

TC 3338-23
Final Report

ELLIOTT BAY ACTION PROGRAM:
EVALUATION OF POTENTIAL CONTAMINANT SOURCES

by

Tetra Tech, Inc.

for

U.S. Environmental Protection Agency
Region X - Office of Puget Sound
Seattle, Washington

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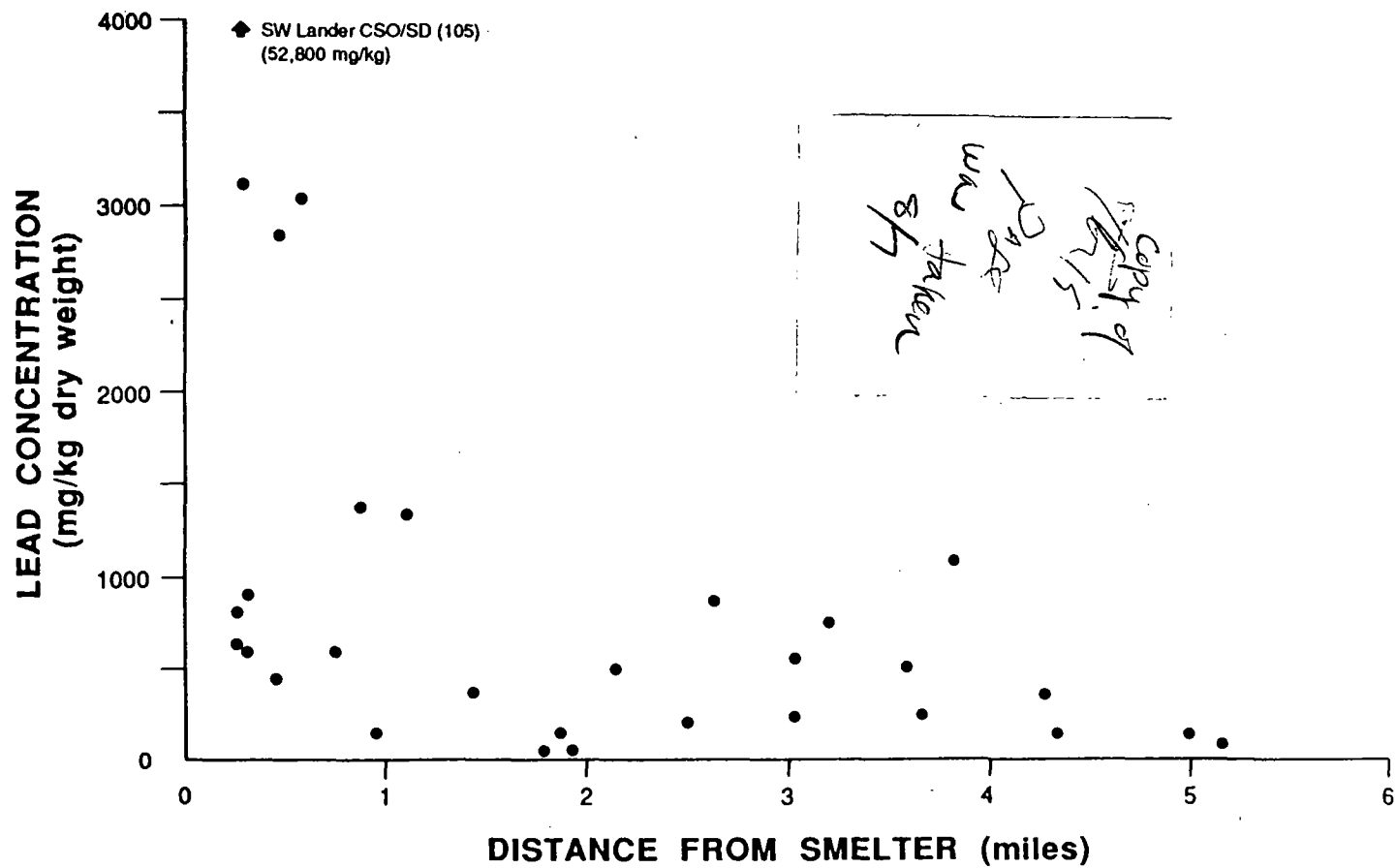


Figure 4-38. Concentrations of lead in drain sediments vs. distance from smelter.

- Development of a storm drain monitoring approach (Tetra Tech 1988g)
- Evaluation of sediment remedial alternatives (Tetra Tech 1988b)
- Development of an environmental monitoring approach (Tetra Tech 1988c).

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EXECUTIVE SUMMARY

INTRODUCTION

In 1985, the Elliott Bay Action Program was initiated by U.S. EPA, Ecology, and other resource management agencies to identify and correct problems associated with toxic contamination of Elliott Bay and the lower Duwamish River. Sampling was conducted during September-October 1985 in the nearshore receiving environment and in combined sewer overflows (CSOs) and storm drains discharging into the Elliott Bay project area. The project area includes the shallow areas (<60 ft deep) of Elliott Bay east of a line from Alki Point to West Point and the lower Duwamish River upstream to the Head of Navigation (Figure ES-1). Results of the receiving environment sampling effort are presented in PTI and Tetra Tech (1988). The results of the drain sampling effort are the subject of this document.

The evaluation of potential contaminant sources (i.e., CSOs, storm drains, industrial facilities, groundwater, spills) in Elliott Bay and the lower Duwamish River provided in this document has two major components:

- Identification and ranking of CSOs and storm drains based on the concentrations of chemical contaminants measured in sediments collected from the drains
- Identification of relationships between potential contaminant sources and the high-priority problem areas identified in the receiving environment (PTI and Tetra Tech 1988).

The results of this evaluation can be used to focus future investigations and source control activities on the highest priority drains and known contaminant sources.

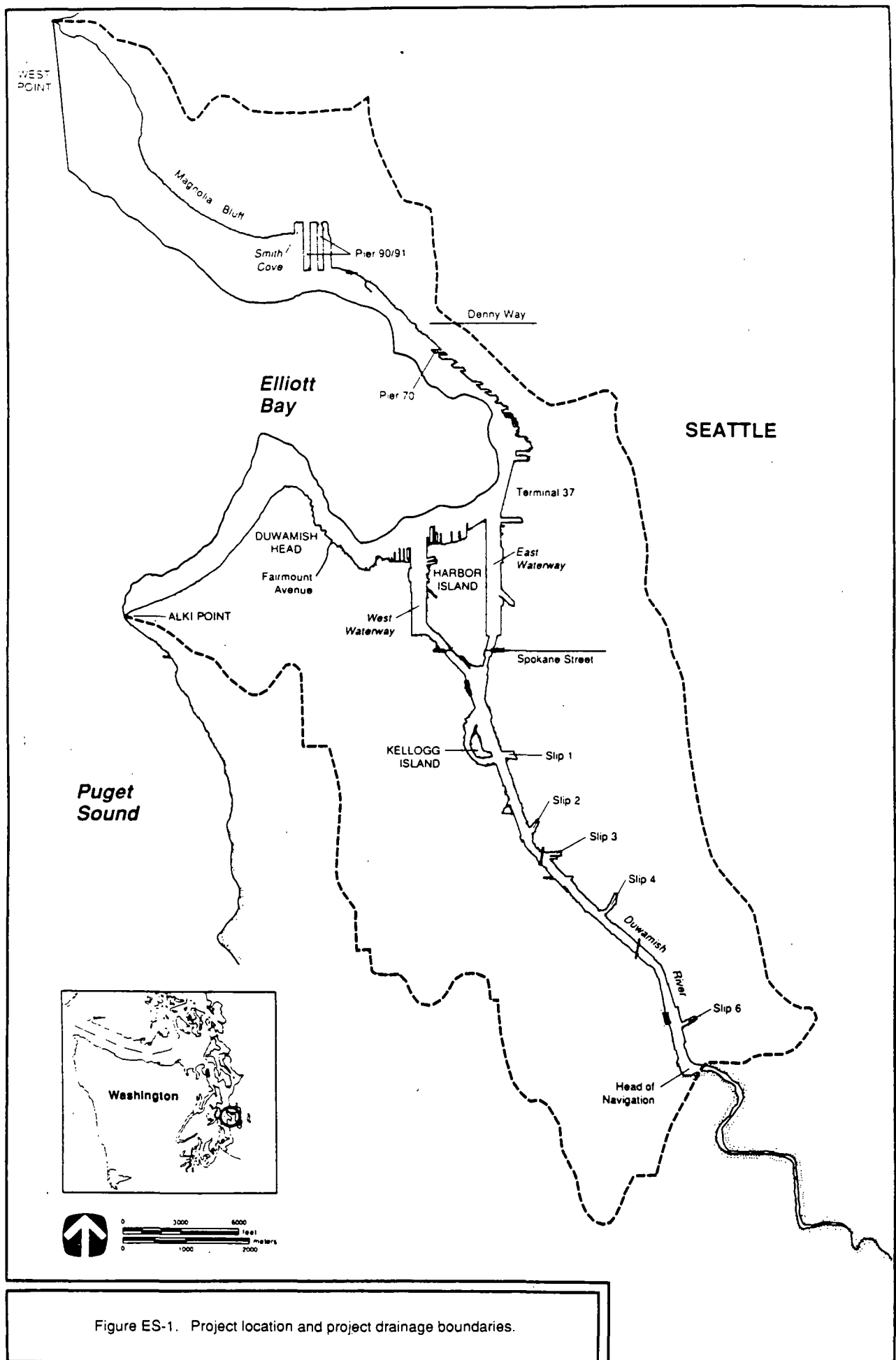


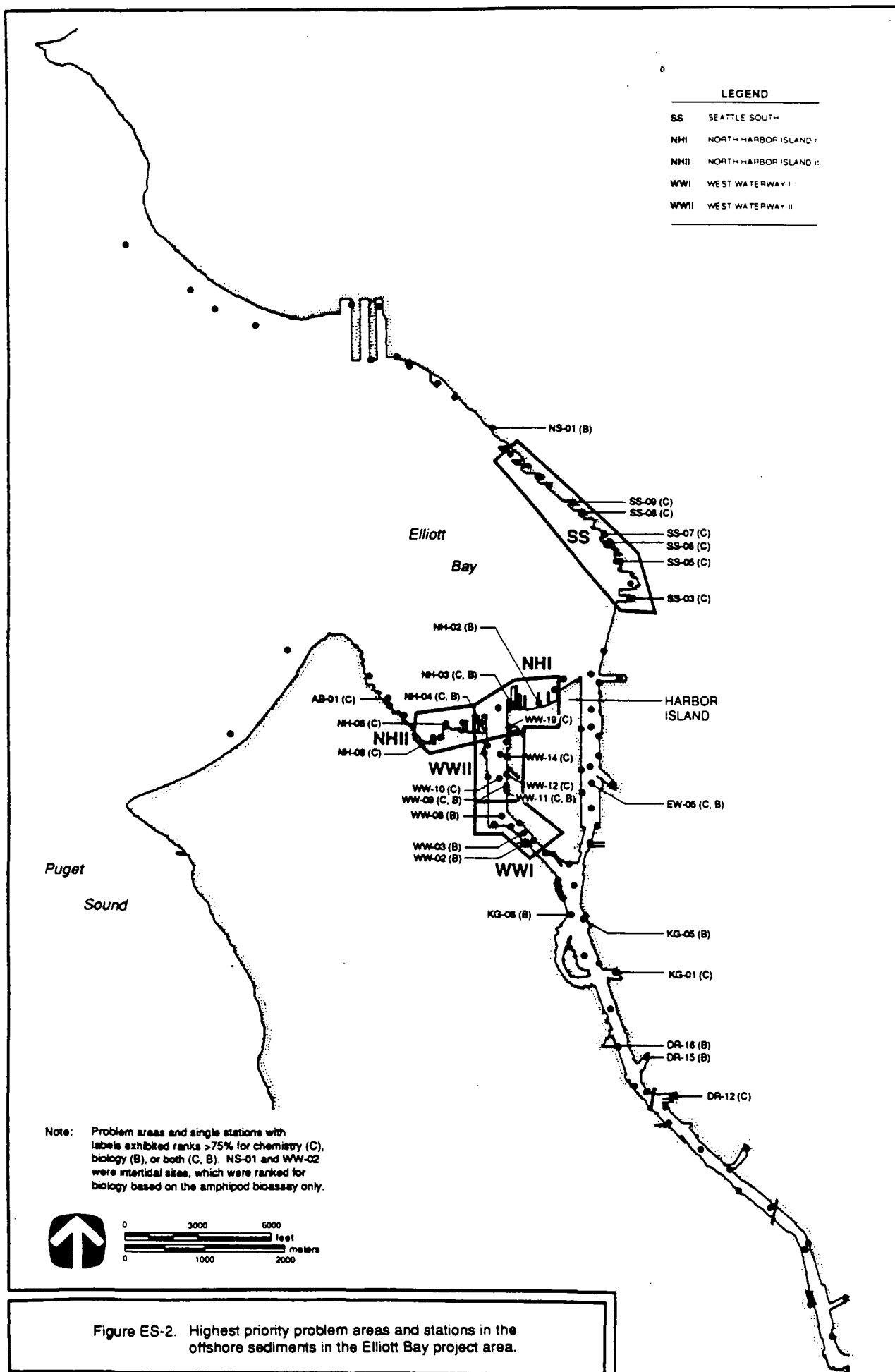
Figure ES-1. Project location and project drainage boundaries.

The field investigation focused on CSOs and storm drains because they constitute the largest category of ongoing sources in the project area. The source sampling approach was based on a technique originally developed by Metro in which contaminants are traced to their ultimate sources through the collection and chemical analysis of in-line sediment samples from individual drains (Metro 1985; Sample 1987; Hubbard and Sample 1988). Because the Elliott Bay source sampling program was designed as a preliminary screening investigation, a single sediment sample was collected only from one manhole located near the mouth of each drain. Samples collected from the downstream end of each drain provided a chemical characterization of sediments composited from the entire drainage basin or service area. Based on the results of the preliminary screening, each drain was evaluated and prioritized for additional contaminant tracing and source identification activities.

The source evaluation section of this report focuses on the high-priority problem areas and problem stations in the receiving environment that were identified in PTI and Tetra Tech (1988) (Figure ES-2). Relationships between the high-priority problem areas and potential sources were identified using available source sediment chemical data, receiving environment sediment chemistry, and ancillary information on drainage basin characteristics, industrial activities, and historical sources.

OVERVIEW OF POTENTIAL SOURCES

Available information on drainage basin areas, discharge locations, contaminant loading, flow rates, permitted facilities, and historical problem sites was used to identify, evaluate, and rank potential sources of contaminants in Elliott Bay and the lower Duwamish River. Potential contaminant sources in the Elliott Bay project area can be divided into seven major categories: wastewater treatment plants, CSOs, industrial discharges, groundwater, atmospheric deposition, surface runoff, and accidental spills.



There are three wastewater treatment plants that discharge treated wastewater into the project area. CSOs include overflows from the City of Seattle combined sewer system and the Metro interceptor system. Industrial sources consist of permitted and nonpermitted discharges of wastewater and stormwater runoff from individual industrial facilities. Industrial discharges may be routed to the waterways via the city storm drain system or private drains. Approved discharges are permitted by Ecology under the National Pollutant Discharge Elimination System (NPDES) program. In addition, industrial facilities may also discharge wastewater to the city combined sewer system. These discharges are permitted through Metro's industrial pretreatment program.

Groundwater sources include any subsurface transport of contaminants into the project area. Atmospheric sources consist of airborne pollutants deposited directly on the water surface. Airborne material deposited initially on the land surface and transported to the waterways via stormwater runoff is categorized as surface runoff. The final category, accidental spills, includes the release of contaminants resulting from spills to the waterways in the project area.

METHODS

Source Evaluation Approach

The approach used to identify problem chemicals and rank problem CSOs and storm drains is based on that described by Tetra Tech (1988g). This approach is consistent with the one used to identify problem chemicals and areas in the receiving environment (PTI and Tetra Tech 1988), thus permitting a comparison of contamination in drains and offshore sediments.

Problem chemicals in each drain were identified based on either of the following criteria:

- Exceedance of a highest Apparent Effects Threshold (AET) value for chemicals where AET values have been derived

- Exceedance of the 90th percentile concentration (defines the concentration above which 10 percent of the observations fall) measured during the source survey for chemicals where there are not available AET values.

The focus of the AET approach is to identify concentrations of chemical contaminants in sediments that are associated with statistically significant biological effects (relative to reference conditions). For a given chemical and a specific biological indicator, the AET is the concentration above which statistically significant biological effects occurred in all samples of sediments analyzed.

Drains whose sediments exceeded a high AET value (HAET) or a 90th percentile concentration for at least one chemical were identified as potential problem drains. Problem drains were ranked based on the following criteria:

- Number of problem chemicals identified in each drain.
- Magnitude of exceedance of reference area sediment chemistry conditions based upon the elevation above reference (EAR) technique. This technique is a comparison of drain sediment data with offshore receiving environment sediment data collected from reference areas (i.e., noncontaminated areas). EAR values are calculated by dividing the measured concentration in the sediments collected from the drain by the reference concentration.
- Contaminant loading index for each drain. Loading indices are not true contaminant loading values, but can be used as an indication of loading potential. Loading indices are calculated as the product of the concentration of the contaminant measured in the drain sediments and the estimated average annual flow for each drain.

The approach used to link potential contaminant sources to contamination in the receiving environment sediments for the highest priority problem areas and stations was based on the following information:

- Proximity of sources to the problem area in the receiving environment
- Comparison of the available source sediment chemistry data from the Elliott Bay initial screening program and Metro's Industrial Non-Point Source Investigation (Metro 1985; Sample 1987; Hubbard and Sample 1988) with available offshore sediment data
- Known or suspected sources of contaminants discharging into a designated high-priority problem area in the receiving environment
- Spatial distribution of contaminants in the offshore sediments
- Past or ongoing practices that may contribute to the contamination observed in the receiving environment.

Source Sampling Approach

Sediment samples were collected from 7 CSOs, 20 storm drains, and 15 CSO/storm drains that discharge into the project area (Figure ES-3). Three of these drains were sampled at more than one location, resulting in a total of 46 drain sediment samples. In some cases, the city and Metro route the overflows from the combined sewer system to area waterways via an existing storm drain system. These outfalls are designated CSO/storm drains (SDs) for the purpose of this report.

Sample collection was performed between 23 September and 17 October 1985. Sediment samples were collected from deposits in the manhole near the

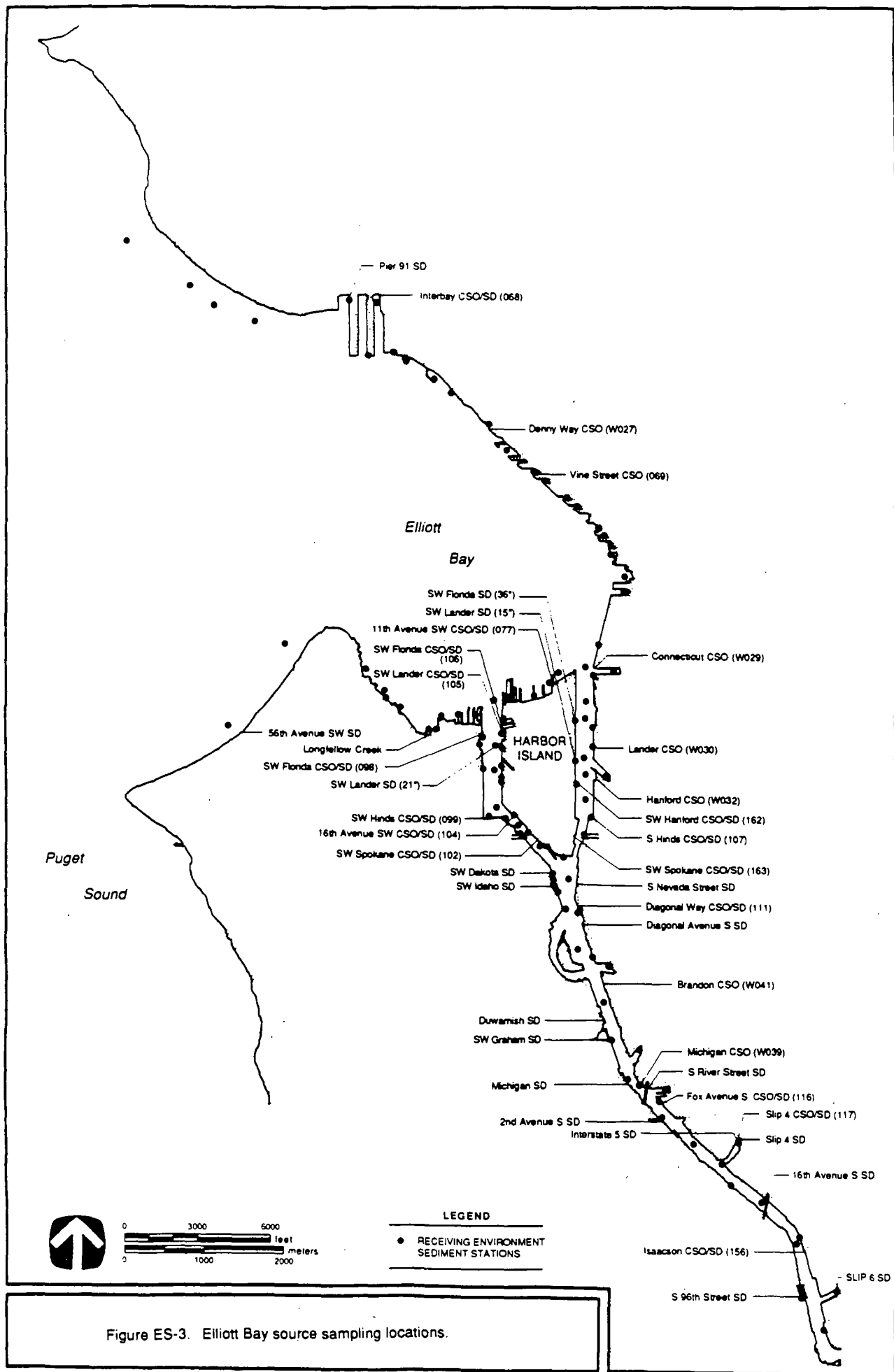


Figure ES-3. Elliott Bay source sampling locations.

mouth of each drain. The samples were analyzed for U.S. EPA priority pollutants and other chemicals that may be currently or have been historically discharged into the project area. The chemical contaminants measured during the source sampling effort are identical to those contaminants analyzed for in the offshore sediments (PTI and Tetra Tech 1988), which facilitated comparisons between variables measured in the two sampling environments.

Procedures specified in the Puget Sound Estuary Program (PSEP) protocols (Tetra Tech 1986c) were used to analyze chemical constituents in the drain sediments and to assess the quality of the data obtained from different laboratories. Based on the quality assurance/quality control (QA/QC) review of the chemical data, a substantial portion of the data set was qualified for a variety of reasons. For example, the QA/QC review included control actions that are not a part of U.S. EPA Contract Laboratory Program or PSEP guidelines for data review (e.g., in accordance with guidance from U.S. EPA Region X, all semivolatile organic compounds detected at $<1,000$ ug/kg dry weight were qualified as estimates based on analysis of sediment reference materials). The data quality issue that most affected data analysis was high detection limits (i.e., low analytical sensitivity) for certain compounds, most notably chlorinated phenols, chlorinated benzenes, hexachlorobutadiene, benzyl alcohol, and benzoic acid. These high detection limits resulted from low surrogate recoveries, as detection limits of acid extractable compounds were adjusted on a chemical-specific basis to reflect surrogate recoveries. However, analyses of sediment from identified problem areas and problem drains that had relatively high chemical concentrations were largely unaffected by the detection limit and analytical sensitivity issues.

INTER-DRAIN COMPARISONS

Identification of Problem Chemicals

The largest number of problem chemicals was observed in the Fox S. CSO/SD (116)-MH3 (32 problem chemicals), followed by the Michigan CSO (W039)

(19 problem chemicals), Slip 4 CSO/SD (117) (16 problem chemicals), Fox S. CSO/SD (116)-MH1 (13 problem chemicals), Slip 6 SD (11 problem chemicals), and Michigan SD (11 problem chemicals). Each of the remaining drains sampled during the study had fewer than 10 problem chemicals.

Lead, identified as a problem chemical in 18 of the 46 drain sediment samples, was the most common problem chemical. Other metals that were identified as problem chemicals included, in order of decreasing frequency of exceedance of HAET or 90th percentile values: cadmium, mercury, zinc, copper, nickel, arsenic, antimony, chromium, selenium, and silver.

Extractable organic compounds that were identified as problem chemicals in drain sediments based on exceedances of an HAET or a 90th percentile concentration included phenol, 2-methylphenol, 4-methylphenol, 2,4-dimethylphenol, low molecular weight polynuclear aromatic hydrocarbons (LPAH), high molecular weight polynuclear aromatic hydrocarbons (HPAH), PCBs, di-n-octyl phthalate, dimethyl phthalate, butyl benzyl phthalate, total phthalates (sum of di-n-octyl, dimethyl, and butyl benzyl phthalates), 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, total chlorinated benzenes, 1-methylphenanthrene, 2-methylphenanthrene, 3-methylphenanthrene, 2-methylnaphthalene, biphenyl, dibenzofuran, benzyl alcohol, benzoic acid, and carbazole. p,p'-DDT, p,p'-DDE, and p,p'-DDD were the most frequently detected pesticides and were identified as problem chemicals based on exceedance of HAET values.

Volatile organic compounds that were identified as problem chemicals in specific drains included total xylenes, trans-1,2-dichloroethene, ethyl benzene, tetrachloroethene, vinyl chloride, and 1,1-dichloroethane. However, in general, volatile organic compounds were detected infrequently in the drain sediment samples relative to receiving environment samples.

CSO and Storm Drain Rankings

The following drains received a high-priority ranking:

- Fox S. CSO/SD (116)
- Michigan CSO (W039)
- Slip 4 CSO/SD (117)
- Duwamish SD
- SW Lander CSO/SD (105)
- SW Hanford CSO/SD (162)
- Slip 6 SD
- Michigan SD.

Two additional drains, the SW Florida CSO/SD (098) and the S. 96th St. SD, were recommended for inclusion on the list of high-priority drains because ongoing sources of contamination have been documented in their drainage basins. Numerous other drains in the project area were identified as contaminant sources based on drain sediment chemistry results. However, the eight drains listed above are the drains that ranked as the highest priority based on the three ranking criteria.

SOURCE EVALUATIONS

A summary of the source evaluations for each high-priority problem area and problem station (Figure ES-2) is presented below. Chemical contamination and an assessment of biological effects in the receiving environment are discussed in PTI and Tetra Tech (1988).

Seattle South Waterfront Problem Area

Decades of historical discharges of untreated sewage and industrial effluent have contributed to the extensive contamination of sediments in

the Seattle South Waterfront problem area. Seventeen chemicals, including six metals (i.e., copper, lead, zinc, mercury, cadmium, and silver), LPAH, HPAH, PCBs, and eight other organic compounds, exceeded the HAET at stations located along the Seattle South Waterfront.

Few industrial facilities are currently located in the area and none have been identified as substantial sources of contamination. Current potential sources of chemical contaminants include seven CSOs and storm drains that discharge along the Seattle South Waterfront. Only one CSO [Vine CSO (069)] contained sufficient sediment to allow sample analysis. Lead, mercury, benzyl alcohol, 2-methylphenol, and LPAH were identified as problem chemicals in the Vine CSO (069). Although several highly contaminated offshore stations were observed near the outfalls of the other CSOs, the role of these CSOs in contributing to offshore contamination cannot be assessed at this time. Other potential sources include waterfront structures and activities associated with marine transportation (e.g., pilings, accidental spills, and ship discharges of grey water and bilge water).

North Harbor Island I Problem Area

The North Harbor Island I problem area was characterized by very high concentrations of several metals (i.e., arsenic, copper, mercury, lead, and zinc), PAHs, and PCBs. Two shipyard facilities are located adjacent to Elliott Bay and the West Waterway and may have been sources of metals and PAH to the North Harbor Island I problem area (especially due to the historical handling of sandblast material). Lead was identified as a problem chemical in many of the storm drains serving Harbor Island and has been associated with historic emissions from a secondary lead smelter that operated there between 1937 and 1984. In addition, a bulk petroleum products storage facility located on the north end of Harbor Island may have been a potential source of PAH. PCBs were also a problem chemical in this area, but no specific sources have been identified. PCBs were widely used historically in electrical equipment and could have contaminated offshore sediments from various sources. Numerous private storm drains discharge into this problem area and are poorly characterized.

North Harbor Island II Problem Area

Contamination in sediments offshore from the North Harbor Island II Problem Area was predominately PAH, with less widespread contamination by PCBs. The distribution of the PAH in sediments of North Harbor Island II problem area suggests that a wood treatment facility and the outflow of lower Longfellow Creek may have been significant sources of this class of compounds. In addition, lower Longfellow Creek was identified as one source of PCBs in this problem area. PCB contamination in this problem area appeared to be patchy, suggesting there were several other potential sources of this class of compounds. Contaminated groundwater underlying the abandoned West Seattle landfill may also have been a source of PAH and other extractable organic compounds.

West Waterway I Problem Area

Localized areas of contamination by organic compounds (particularly PAH and PCBs) were observed in the West Waterway I problem area. The SW Spokane St. CSO/SD (102) was the only drain of those sampled in this problem area where a relationship between the contaminants (i.e., zinc and PCB) in the receiving environment and drain sediments was observed. Other drains (and associated contaminants) discharging to the problem area are the SW Hinds CSO/SD (099) (4-methylphenol) and the 16th Ave. SW CSO/SD (104) (1-methylphenanthrene, 2-methylphenol, lead, and p,p'-DDT). The Chelan St. CSO (W036) may have been a potential source of contaminants because of the presence of industrial facilities in its drainage basin. However, the Chelan St. CSO (W036) was not sampled because of insufficient sediment. Several waterfront industrial facilities were identified as potential nonpoint sources of contamination based on the nature of their activities, and in some cases qualitative and/or quantitative data.

West Waterway II Problem Area

In the West Waterway II problem area, chemical contamination in the offshore sediments exhibited two general spatial patterns: 1) metal contamination that was concentrated on the east side of the waterway, and 2) generally elevated concentrations of PAH and PCBs throughout the area. The lead concentration (52,800 mg/kg) in the SW Lander CSO/SD (105) sediment was by far the highest concentration reported during this source investigation. A secondary lead smelter previously located on Harbor Island was likely the primary source of lead contamination observed in the SW Lander CSO/SD (105) and in sediments on the east side of the West Waterway II problem area. Other metals in sediments along the east side of the waterway may have originated from historical operations at a shipyard facility.

In addition, the SW Florida CSO/SD (116) could have been a potential source of the metals contamination in the offshore environment. No problem chemicals were identified in the SW Florida CSO/SD (098) sediment at the station sampled in 1985 during this study. However, the sediment sample was collected shortly after the drain was cleaned by the City of Seattle. Sediment samples collected by Metro in 1984 and 1986 from upstream catch basins on the wood treatment facility property were contaminated with metals, HPAH, LPAH, PCBs, and pentachlorophenol (Sample, T., 27 March 1987, personal communication; Hubbard and Sample 1988). Therefore, the SW Florida CSO/SD (098) is likely an ongoing source of contaminants to the West Waterway II problem area.

Problem Station NS-01

Intertidal Station NS-01 was located north of Pier 70 and less than 250 ft from the Denny Way CSO (W027), the largest and most frequent combined sewer overflow site on Elliott Bay. Silver exceeded the HAET concentration at Station NS-01. Problem chemicals identified in the Denny Way CSO (W027) sediment sample included silver, mercury, and 1-methylphenanthrene. The relative distribution of metals and LPAH in the sediment of the Denny Way CSO (W027) was similar to the relative distribution of metals and LPAH in

sediments at Station NS-01. However, the relative distribution of HPAH in sediments at each location was less similar.

Known discharges to the Denny Way CSO (W027) system include printers, graphic and photographic shops, industrial laundries, and an electroplating facility (Romberg et al. 1987). Printing and photography operations may be historical sources of silver, and the industrial laundries may have contributed cadmium, nickel, lead, zinc, and mercury contaminants. Silver reclamation at printing and photographic shops and pretreatment equipment at the industrial laundries are expected to reduce contaminant loading from these sources to the Denny Way CSO system (Romberg et al. 1987).

Problem Station EW-05

Station EW-05 was located in the center of the East Waterway between Terminals 25 and 30. Problem chemicals identified in Station EW-05 sediments included PAH, cadmium, PCBs, and mercury. The Hanford CSO (W032) and the SW Hanford CSO/SD (162) are south of and relatively close to Station EW-05. The Hanford CSO (W032) discharges in the immediate vicinity of Station EW-05 and the relative distribution of metals in its sediments was similar to that of Station EW-05 sediments (with the exception of chromium). Sediments from both locations were significantly contaminated with PAH. The SW Hanford CSO/SD (162) discharges about 500 ft south of Station EW-05. With the exception of copper, the relative distribution of metals in sediments from the two locations was similar. The Hanford CSO (W032) and the SW Hanford CSO/SD (112) were likely contributors to the sediment contamination at Station EW-05 based on their proximity to Station EW-05, the similarity in problem chemicals, and, to a lesser extent, the similarity in the relative distribution of contaminants in the sediments.

The Lander CSO (W30) discharges to the East Waterway north of Station EW-05. Although the station (Station EW-09) directly offshore of the Lander CSO (W30) did not exhibit an elevated cadmium concentration, cadmium was measured at 33.8 mg/kg in sediment collected from the Lander CSO. Therefore, the CSO may be a source of cadmium to the East Waterway. Industrial

facilities in the Lander CSO (W30) drainage include metal recycling and plating operations.

Concentrations of PCBs were not highly elevated in the sediments of drains discharging into the east side of the waterway. However, PCB concentrations in the sediments of drains on the west side of the waterway (i.e., SW Florida SD and SW Lander SD) exceeded the low AET (LAET) concentration (130 ug/kg), and the SW Hanford CSO/SD (162) contained PCBs at highly elevated concentrations. A metal recycler and an oil recycler have been identified as potential PCB sources within drainages to the East Waterway. Potential PAH sources in the East Waterway include bulk petroleum storage facilities and many diffuse sources.

Problem Station AB-01

Station AB-01 was located east of Duwamish Head. Problem chemicals identified in this area included LPAH, mercury, copper, and zinc. No sources of contaminants have been identified near Problem Station AB-01. The nearest discharges to this problem station are the SW Fairmount SD and the SW Fairmount CSO (078), both of which serve primarily residential areas. Contamination at this station may be due to historical shoreline activities or spills from ships.

Problem Station KG-01

Problem Station KG-01 was located near the mouth of Slip 1 across from the southern end of Kellogg Island. This problem station was characterized by elevated concentrations of metals (i.e., cadmium, zinc, and mercury), HPAH, and phthalates. The Brandon CSO (W041) discharges approximately 1,000 ft south of Station KG-01. Despite the distance between the two sites, similarity between the relative distribution of contaminants and problem chemicals at each site suggests that the Brandon CSO (W041) may have been a source of the contamination observed at Station KG-01. Potential sources of metals to the Brandon CSO (W041) include an abandoned landfill, a metal plater, a tank cleaning service, and a manufacturer of aircraft

equipment. PAH contamination in the Brandon CSO (W041) may have been caused primarily by nonpoint sources. Other potential sources of contamination in Slip 1 include eight unidentified subtidal drains.

Problem Stations KG-05 and KG-06

Stations KG-05 and KG-06 were approximately 550 ft apart and were located in the Duwamish River north of Kellogg Island. Contaminants observed at KG-05 included cadmium, lead, mercury, zinc, and PCBs. At Station KG-06, arsenic, PCBs, p,p'-DDT, and other organic compounds were identified as problem chemicals. The Diagonal Way CSO/SD (111) and the Diagonal Ave. S. SD discharge within 1,000 ft of these problem stations. Due to dissimilarities between sediment contamination patterns in the drains and the problem stations at the time of sampling, these drains could not be linked to contamination observed in the offshore sediments. Two Metro CSOs (W034 and W035) also discharge in the vicinity of these problem stations. The drainage system associated with these CSOs is not well characterized, but serves all of Harbor Island and the industrial waterfront on the west side of the Duwamish River, and may be a transport route for contaminants.

Problem Station DR-12

Station DR-12 was located in Slip 3 on the Duwamish River. The Fox S. CSO/SD (116) discharges into the Duwamish River approximately 200 ft south of Slip 3. Arsenic, zinc, and copper were identified as problem chemicals in sediments from both the Fox S. CSO/SD (116) and Station DR-12. The Fox S. CSO/SD (116)-MH3 contained a total of 32 problem chemicals, the largest number in the present study. Based on proximity and the close similarity in sediment chemistry between the Fox S. CSO/SD (116) and Station DR-12, the Fox S. CSO/SD (116) may have been a source of sediment contamination observed at Station DR-12. In addition, historical practices at the shipyard along the south shoreline of Slip 3 may have been responsible for metals contamination in Slip 3 sediments. No other facilities along the Slip 3 shoreline have been identified as potential contaminant sources.

Problem Station DR-15

Station DR-15 was located in Slip 2 in the Duwamish River. Station DR-15 was designated as a problem station because severe biological effects were observed there. In the sediment from Station DR-15, di-n-octyl phthalate exceeded the 90th percentile concentration, and PCBs exceeded the LAET concentration. No contaminant sources have been identified in the vicinity of Station DR-15. However, the Michigan CSO (W039) and the SW Michigan SD (approximately 800 and 1,200 ft south of Station DR-15, respectively) were possible sources of some of the phthalate contamination observed at Station DR-15. This conclusion is based on the proximity of the drains to the problem station and similarities of chemical contamination between the drains and the problem station.

Problem Station DR-16

Station DR-16 was located north of Terminal 115 on the western side of the Duwamish River. Because severe biological effects were observed at Station DR-16, it was designated as a problem station. Contaminants observed at Station DR-16 included HPAH, butyl benzyl phthalate, PCBs, zinc, and LPAH. No ongoing potential sources were identified in the vicinity of this problem station. The SW Graham SD is located less than 100 ft from Problem Station DR-16, but could not be linked to the contamination observed in offshore sediments due to the absence of problem chemicals in drain sediments. Historical activities in the area may have resulted in past or ongoing contaminant transport (e.g., via contaminated groundwater seepage) to the Duwamish River near Station DR-16.

1.0 INTRODUCTION

The U.S. EPA and Ecology, in cooperation with other resource management agencies, initiated the Elliott Bay Action Program in 1985 to identify and correct problems associated with toxic contamination of Elliott Bay and the lower Duwamish River. An interim work plan for the program (Tetra Tech 1985b) was developed based on a preliminary assessment of toxic problems areas (Tetra Tech 1986b), and a review of existing plans for corrective actions (Tetra Tech 1985c).

During September to October 1985, sampling was conducted in the nearshore receiving environment and in CSOs and storm drains in Elliott Bay and lower Duwamish River. Sampling was performed to supplement existing information and to provide a detailed assessment of toxic contamination and specific problem chemicals. The source sampling effort focused on CSOs and storm drains because they constitute the largest category of active point sources in Elliott Bay and the lower Duwamish River. Results of the receiving environment sampling effort are presented in PTI and Tetra Tech (1988).

An identification and evaluation of potential contaminant sources in Elliott Bay and the lower Duwamish River is provided in this document. The objectives of the source evaluation effort included the following steps:

- Identify and rank CSOs and storm drains based on the contaminant concentrations measured in sediment collected from the drains (September-October 1985)
- Link potential contaminant sources to the problem areas observed in the offshore receiving environment.

The results of this evaluation can be used to focus future investigations and source control activities on the highest priority drains and known contaminant sources.

The source evaluation section of this report focuses on the high-priority problem areas in the receiving environment that were identified in "Analysis of Toxic Problem Areas" (PTI and Tetra Tech 1988). Relationships between the high-priority problem areas and potential sources were identified using available source sediment chemical data (e.g., this study; Metro 1985; Sample 1987; Hubbard and Sample 1988), receiving environment sediment chemistry (e.g., Romberg et al. 1984; Malins et al. 1980) and ancillary information on drainage basin characteristics, industrial activities, and historical sources.

1.1 DESCRIPTION OF PROJECT AREA

Elliott Bay is a small embayment (8 mi^2) located on the eastern shore of Puget Sound approximately midway between Admiralty Inlet and the Tacoma Narrows (Figure 1-1). The inner bay receives fresh water from the Duwamish River and most of the stormwater runoff from the highly developed drainage basin in metropolitan Seattle. The nearshore areas of Elliott Bay have been altered substantially from their natural state by anthropogenic activities.

The Duwamish River is a salt-wedge estuary, influenced by tidal action over its lower 10 mi (including all of the riverine habitat within the project area). Harbor Island divides the river into the East and West Waterways near the mouth. The lower 6 mi of the Duwamish River were straightened to improve navigation through the heavily industrialized areas of the city. The Duwamish drainage basin (480 mi^2) includes large expanses of agricultural and forested lands in the upper portion of the basin.

The project area includes the shallow areas ($<60 \text{ ft}$ deep) of Elliott Bay east of a line from Alki Point to West Point and the lower Duwamish River upstream to the Head of Navigation (see Figure ES-1). The immediate drainage basin of Elliott Bay and the lower Duwamish River consists of about 26 mi^2 of highly developed land in metropolitan Seattle. Boundaries of the

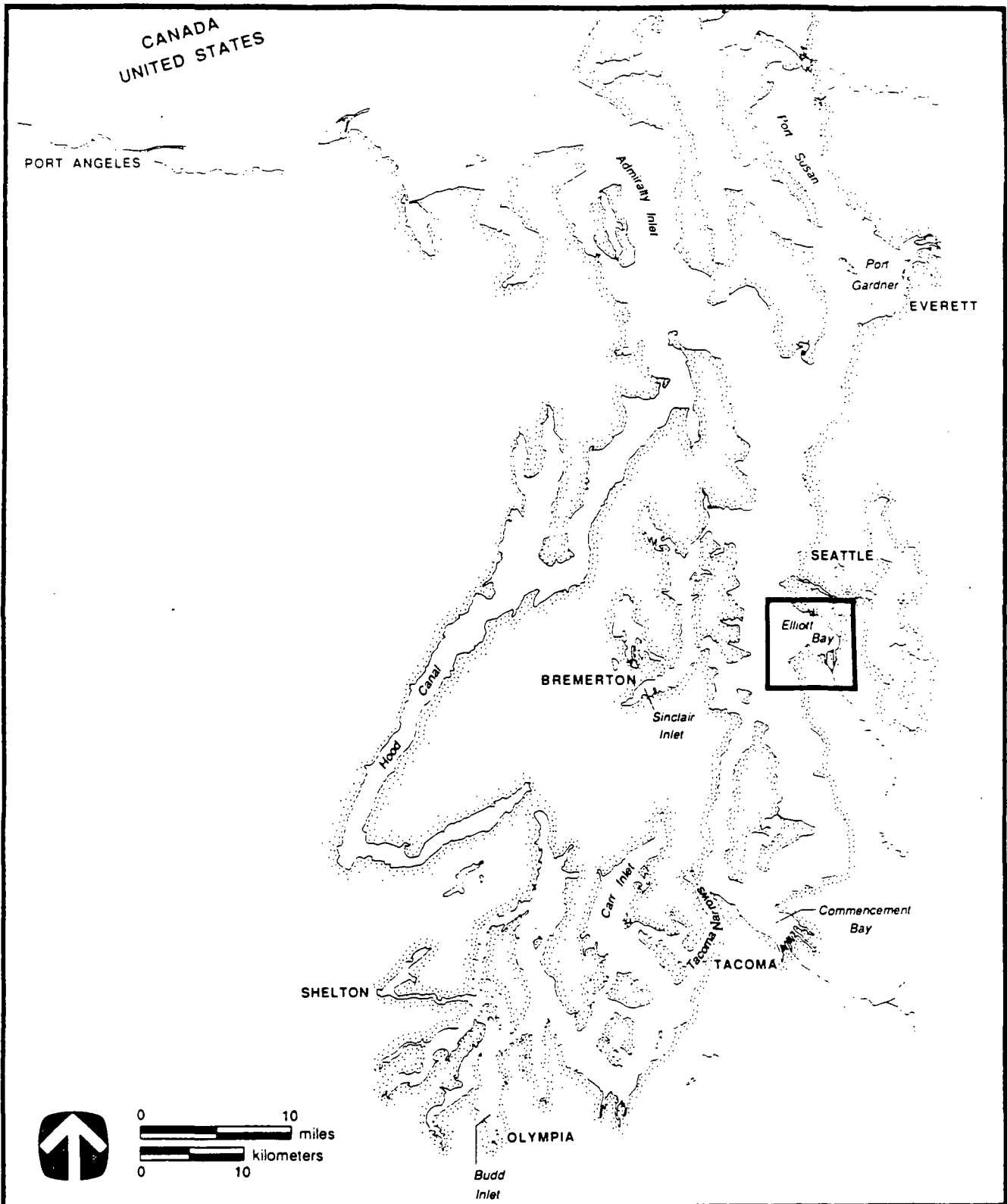
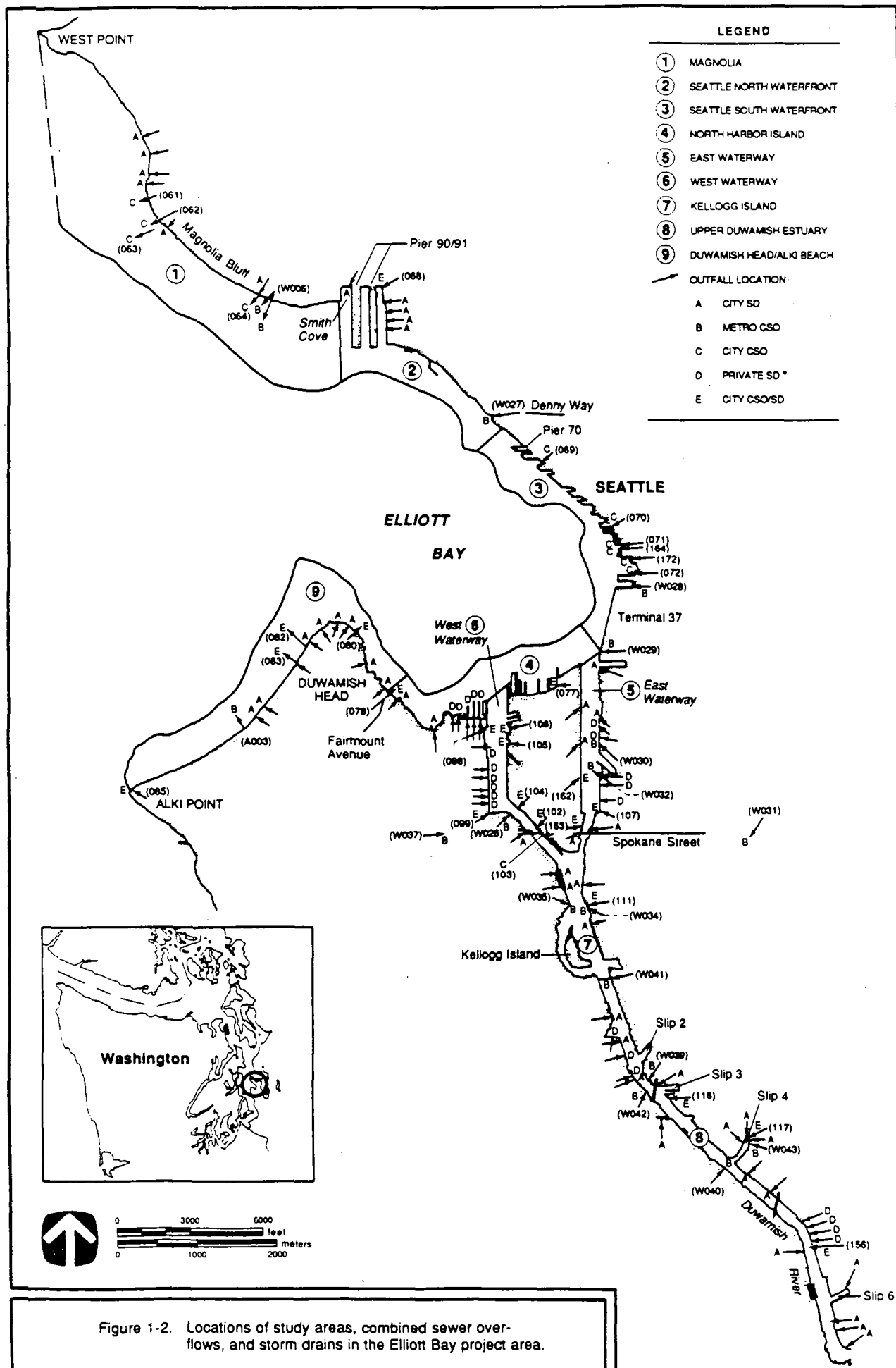


Figure 1-1. Elliott Bay and the lower Duwamish River project area.

drainage basin considered in this study are roughly defined by Beacon Ave. on the east side and 35th Ave. SW on the west side. The basin includes residential areas in the southern portions of the Queen Anne and Magnolia neighborhoods, and most of West Seattle; the industrial areas along the Duwamish Waterway; the I-5 corridor from James St. to about S. Dawson St.; and the downtown business district.

A major objective of this report is to link potential contaminant sources to problem areas observed in the nearshore region of Elliott Bay and the lower Duwamish River. To facilitate spatial analysis, the nearshore region has been divided into nine smaller study areas based on geographic features and locations of major contaminant sources (CSOs and storm drains) (Figure 1-2). Area boundaries and major features are listed below:

- Magnolia (West Point south to Smith Cove)
- Seattle North Waterfront (Terminals 90 and 91 to Pier 70; Myrtle Edwards public fishing pier)
- Seattle South Waterfront (Pier 70 to Terminal 37; main Seattle waterfront, ferry terminals, Seattle Aquarium, public fishing pier)
- North Harbor Island (southern end of Elliott Bay from Terminal 37 west to Fairmount Ave.; northern Harbor Island)
- East Waterway (mouth to Spokane St. bridge)
- West Waterway (mouth to Spokane St. bridge)
- Kellogg Island (Spokane St. bridge to Kellogg Island/Slip 1)



- Upper Duwamish Estuary (Kellogg Island/Slip 1 to Head of Navigation)
- Duwamish Head/Alki Beach (eastern shoreline of Duwamish Head, north of Fairmount Ave. SW to Alki Point).

1.2 OVERVIEW OF REPORT

An overview of potential sources in the Elliott Bay project area is provided in Section 2.0. The approach used to identify and prioritize sources of toxic contaminants is presented in Section 3.0. A summary of the source sampling approach is also provided in Section 3.0. Inter-drain comparisons are presented in Section 4.0. Analysis of the drain sediment data included the following components 1) identification of problem chemicals and sediment characteristics in each drain, 2) inter-basin comparisons of drains, 3) comparisons with historical drain data, 4) evaluation of additional relationships between drains and sources in the basin; and 5) prioritization of drains based on sediment contamination. In Section 5.0, the distributions of chemicals in source sediments are compared with distributions in the offshore receiving environment to link potential contaminant sources to problem areas offshore. In addition, in Sections 4.0 and 5.0, information provided by agencies involved in the Elliott Bay Action Program is used to identify other potential sources (e.g., nonpoint sources, direct discharges to the waterways, spills) contributing to the contamination in the problem areas.

The following eight appendices are provided in this document:

- Appendix A - Chemical contaminant data for the drains sampled
- Appendix B - Lists of potential contaminant sources in the Elliott Bay project area
- Appendix C - Lists of Metro industrial pretreatment permits and Metro monitored facilities

- Appendix D - Comparisons of grain-size characteristics in the sediments of the drains and offshore receiving environment
- Appendix E - Summary of field conditions during the drain sampling effort
- Appendix F - Elevation above reference values and loading index tables for drains
- Appendix G - Dredging history in the project area
- Appendix H - Uses of problem chemicals identified in the Elliott Bay project area.

In addition, a map appendix is bound separately and contains the following four maps:

- Map 1. Service area boundaries for City of Seattle CSOs in the Elliott Bay project area
- Map 2. Service area boundaries for Metro CSOs in the Elliott Bay project area
- Map 3. Drainage basin boundaries for non-private storm drains in the Elliott Bay project area
- Map 4. Locations of potential contaminant sources identified in the Elliott Bay project area.

2.0 OVERVIEW OF POTENTIAL SOURCES

Potential contaminant sources in the Elliott Bay project area can be divided into seven major categories: wastewater treatment plants, CSOs, surface runoff, groundwater, industrial discharges, atmospheric deposition, and accidental spills. There are three wastewater treatment plants in the project area: West Point, Renton, and Alki. CSOs include overflows from the City of Seattle combined sewer system and the Metro interceptor system. Surface runoff occurs when excess precipitation washes off the land surface and discharges to the waterways from storm drains, natural drainages, and direct surface runoff. Groundwater sources include any subsurface transport of contaminants into the project area.

Industrial sources consist of permitted and nonpermitted discharge of wastewater and stormwater runoff from individual industrial sites. Industrial discharges may be routed to the waterways via the city storm drain system or private drains. These discharges are permitted by Ecology under the National Pollutant Discharge Elimination System (NPDES) program. In addition, industrial facilities may also discharge wastewater to the city combined sewer system. These discharges are permitted through Metro's industrial pretreatment program. Atmospheric sources consist of airborne pollutants deposited directly on the water surface. Airborne material deposited initially on the land surface and transported to the waterways via stormwater runoff is categorized as surface runoff. The final category, accidental spills, includes the release of contaminants resulting from spills to the waterways in the project area.

The following sections provide background on the major potential contaminant sources present in the project area and summarize available information on discharge locations, drainage basin areas, flow rates, permitted facilities, contaminant loading, and historical problem sites.

2.1 WASTEWATER TREATMENT PLANTS

West Point, Alki, and Renton wastewater treatment plants are located in the project area. However, the outfalls from each plant extend well offshore, and therefore, do not discharge to the nearshore areas that were the focus of this investigation. The West Point outfall is located approximately 3,650 ft offshore of the northwest corner of Magnolia at a depth of about 210 ft. The Alki outfall is located southwest of Alki Point approximately 1,100 ft offshore at a depth of about 85 ft. The outfall from the Renton plant has recently been moved to an area offshore of Duwamish Head. Prior to 1987, effluent from the Renton plant was discharged to the Duwamish River about 13 mi upstream of the project area near Tukwila. The Renton outfall currently discharges about 9,500 ft offshore of Duwamish Head at a depth of about 600 ft. Available contaminant loading information for the three treatment plants was summarized in Tetra Tech (1986b).

2.2 COMBINED SEWER OVERFLOWS

The majority of the project area is served by a combined sanitary and storm sewer system. Combined sewer overflows result from an overload of the combined system. During a large rainstorm, the additional flow from stormwater runoff exceeds the hydraulic capacity of the collection system. The excess flow, a mixture of stormwater runoff and raw sewage, is discharged into the surrounding waterways from overflow points in the system. This discharge is termed a CSO. There are 48 CSO discharge points in the project area; 17 are in Metro's interceptor system and 31 are in the City of Seattle's collector system. Estimated annual overflow volumes for each CSO are summarized in Table 2-1.

2.2.1 City of Seattle CSOs

The City of Seattle maintains the smaller sewer collector and trunk lines. Locations of the 31 city CSOs and their service area boundaries are shown in Map 1 (see Map Appendix). Service area information was obtained from the city's NPDES permit file. The Fairmount SW (078), SW Maryland (080), SW Jersey (082), SW Arkansas (083), and Point Place SW (085) CSOs are

TABLE 2-1. ESTIMATED ANNUAL DISCHARGES FROM
CITY OF SEATTLE AND METRO CSOs

NPDES CSO Permit Codes ^a	CSO Discharge Points	Service Area (ac)	Historic Flow Rate ^b (Mgal/yr)	Current Flow Rate ^c (Mgal/yr)
Magnolia				
061	W. Raye St.	50	0	0
062	W. Halliday St.	170	0	0
063	W. Halliday St.	170	13	0
064	32nd Ave. W.	53	0	0
W006	Magnolia	740	0	0
Seattle North Waterfront				
068	Interbay	308	72	28
W027	Denny Way	1,885	84-620	370
Seattle South Waterfront				
069	Vine St.	140	35	9
070	University St.	87	2	3
071	Madison St. ^d	53	1	0.7
164	Madison St. ^d	53	1	0.7
172	Columbia St.	4	0	0
072	S. Washington St.	118	17	0.8
W028	King St.	269	8-64	70
W029	Connecticut St.	663	28-93	90
North Harbor Island				
077	11th Ave. SW	204	0	0
168	SW Myrtle St. ^e	408	77	0
169	SW Barton St. ^e	199	39	0
170	24th Ave. SW	35	8	0
Alki Point				
078	Fairmount Ave. SW	282	0.4	0
080	SW Maryland	12	3	0
082	SW Jersey	5	0	0
083	SW Arkansas	42	6	0
085	Point Place SW	5	0	0
A003	Alki	NA ^f	NA	0

TABLE 2-1. (Continued)

NPDES CSO Permit Codes ^a	CSO Discharge Points	Surface Area (ac)	Historic Flow Rate ^b (Mgal/yr)	Current Flow Rate ^c (Mgal/yr)
West Waterway				
098	SW Florida	144	0	0
099	SW Hinds	185	41	11
W036	Chelan	2,034	<1-49	25
W037	Harbor ^g	478	16-49	55
103	SW Spokane	337	0	0
102	SW Spokane	133	0	0
104	16 Ave. SW	133	0	0
105	SW Lander	204	0	0
106	SW Florida	204	0	0
East Waterway				
162	SW Hanford	133	0	0
163	SW Spokane	133	0	0
107	S Hinds	45	0	0
W032	Hanford 2	255	0-700	270
W030	Lander	552	21-330	215
Kellogg Island				
W035	West Siphon	NA	NA	NA
W034	East Siphon	NA	NA	130
111	Diagonal Way	4,003	49.3	68
W031	Hanford 1	4,003	77-480	410
Duwamish River				
W041	Brandon	247	5-30	35
W039	Michigan	1,085	87-210	250
116	Fox S.	26	0	0
117	Slip 4	75	0	0
W043	E. Marginal PS	4,403	NA	NA
156	Isaacson	184	0	0
W044	Norfolk	4,085	<1-140	4
W040	8th Ave. S.	306	<1-18	15
W042	SW Michigan	204	<1-5	2

^a City CSOs are identified with a three digit numerical code. Metro CSOs are identified with W (West Point plant service area) or A (Alki plant service area).

^b Metro flow rate data for 1975-1976, 1981-1983 Computer Augmented Treatment and Disposal System (CATAD), and city flows from NPDES permits.

^c Metro flow rate data received from Metro (1988). City flow rate data from Brown and Caldwell (1988).

^d Outfalls serve same overflow point. Volumes summed.

^e Overflows to North Harbor Island via Longfellow Creek.

^f NA = Not available.

^g Overflows to West Waterway via SW Hinds CSO/SD (099).

located in the Alki wastewater treatment plant collection system (see Table 2-1). All other city CSOs in the project area are in the West Point wastewater treatment plant collection system.

Many of the city's CSOs are classified as emergency overflows. Discharge from emergency overflows is not associated with a storm event, but results from an equipment or power failure. Emergency overflows are generally located at all lift stations to discharge excess flow if the pump fails. The following emergency overflows exist in the city system:

- W. Raye (061)
- W. Halliday (062, 063)
- 32nd Ave. SW (064)
- S. Washington (072)
- Fairmount SW (078)
- SW Maryland (080)
- SW Jersey (082)
- SW Arkansas (083)
- Point Place SW (085)
- SW Spokane (102)
- Slip 4 (117)
- Isaacson (156).

The City of Seattle has implemented control plans to reduce CSOs in several areas. The following city CSOs are no longer active (i.e., overflow only during extreme events, once in 5 yr or more):

- SW Jersey (082)
- Columbia (172)
- Fox (116)
- SW Myrtle (168)
- SW Barton (169)
- 24th Ave. SW (170).

2.2.2 Metro CSOs

Metro operates the larger interceptor system, which transports wastewater from the city collector system to the area treatment plants. Most of the project area lies within the south service area of the West Point wastewater treatment plant. Only a small part of west Seattle is outside the West Point service area. This area is served by the Alki wastewater treatment plant. Metro plans to route baseflow from the Alki system to the Renton plant for secondary treatment and to use the Alki plant only during storm events to provide primary treatment for CSO discharges.

A schematic of Metro's West Point south service area is presented in Figure 2-1. The system consists of two main interceptor lines, the Elliott Bay interceptor which runs along the east side of the Duwamish River, and the West Marginal Interceptor, which runs along the west side of the Duwamish River. There are 17 overflow points on the West Point south service area system. Service area boundaries for each of the CSOs are shown in Map 2 (see Map Appendix). Service area information was obtained from Culp-Wesner-Culp Consulting Engineers and Ott Water Engineers (1986), sewerage plans from the City of Seattle (1:2,400 scale), and Metro personnel

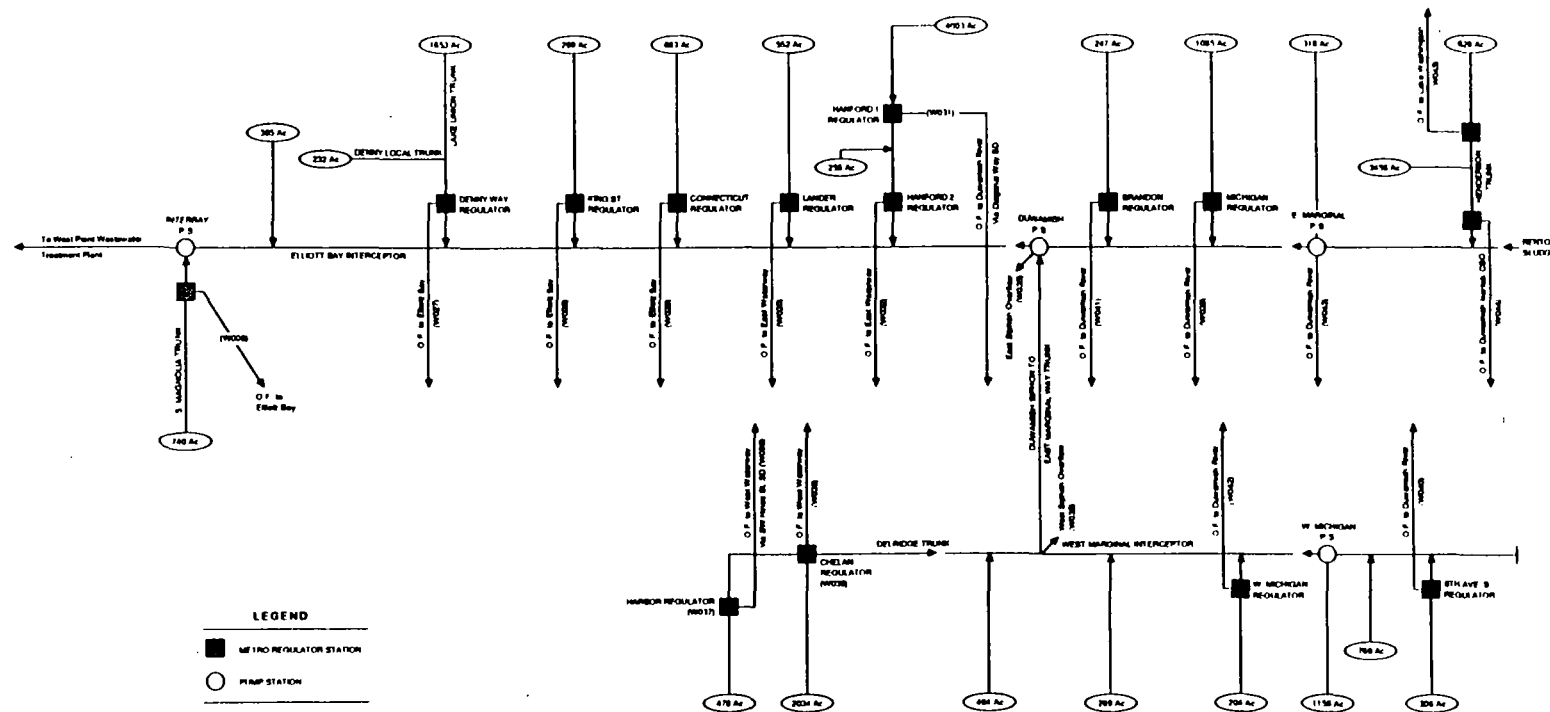


Figure 2-1. Schematic of Metro combined sewer system.

(Cox, E., 12 November and 18 December 1987, personal communication). The three largest service areas whose overflows discharge into the project area are Hanford 1 (4,003 ac), Chelan (2,034 ac) and Denny Way (1,885 ac).

Total annual discharge from Metro CSOs in the project area, estimated at 1,941 Mgal/yr (Culp-Wesner-Culp Consulting Engineers and Ott Water Engineers 1986), accounts for about 94 percent of the total annual CSO flow released to the project area (see Table 2-1). The Denny Way, Lander, Hanford 1 and 2, and Michigan CSOs account for about 80 percent of the total Metro discharge. Discharge from Metro CSOs is automatically regulated by Metro's Computer Augmented Treatment and Disposal System (CATAD). This system is designed to help regulate flow and thereby minimize CSO discharge. Total flow recorded by the CATAD system for 1975, 1976, and 1981-1983 indicate that total Metro CSO discharges may range between 600 and 2,800 Mgal/yr. The large variations in annual flow are largely attributable to variations in precipitation, but are also related to the flexibility in the system created by CATAD.

Pollutant loading data are available for the Michigan CSO, Lander CSO, Denny Way CSO, and Hanford CSO from sampling conducted by Metro as part of the Toxicant Pretreatment Planning Study (TPPS) (Cooley and Matasci 1984). Four overflow events in each CSO were monitored between January and April, 1982. The contaminant concentrations measured in the CSO discharges and the estimated average annual loads for the four Metro CSOs are summarized in Table 2-2.

Additional data, also collected as part of TPPS, are available for King CSO and Harbor CSO. However, samples from these additional CSOs were not collected during overflow events. These stations were sampled to evaluate contaminant characteristics of different land uses in the West Point service area. Twenty-four hour, flow-proportioned composite samples were collected from the regulator structure or pump station at each CSO on 13-18 separate days. The contaminant concentrations and estimated loading based on average annual discharge in each of these two CSOs are presented in Table 2-2.

TABLE 2-2. SUMMARY OF AVAILABLE METRO CSO
CONTAMINANT LOADING DATA

	Mean Concentration (ug/L)						Estimated Load ^a (lb/yr)					
	Michigan ^b (W039)	Lander ^b (W030)	Denny Way ^b (W027)	Hanford ^b (W032)	Harbor ^c (W037)	King ^c (W028)	Michigan (W039)	Lander (W030)	Denny Way (W027)	Hanford (W032)	Harbor (W037)	King (W028)
Antimony	2	3.4	2.4	1.2	1.6	3.6	5.0	7.3	8.9	3.2	0.9	2.5
Arsenic	9.7	11	10	11	4.8	1.8	24.3	23.7	37.1	29.8	2.6	1.3
Cadmium	4.6	5.7	2.6	2	2.6	1.2	11.5	12.3	9.6	5.4	1.4	0.8
Chromium	43	100	26	24	19	35	107.7	215.5	96.4	64.9	10.5	24.6
Copper	63	160	75	50	98	97	157.8	344.8	278.1	135.3	54.0	68.0
Lead	240	140	170	140	180	66	601.3	301.7	630.4	378.8	99.2	46.3
Mercury	0.34	0.2	0.53	0.4	0.68	0.42	0.9	0.4	2.0	1.1	0.4	0.3
Nickel	30	80	32	27	23	23	75.2	172.4	118.7	73.1	12.7	16.1
Silver	4.8	3.7	17	6	2.9	1.6	12.0	8.0	63.0	16.2	1.6	1.1
Zinc	210	290	230	190	260	180	526.2	624.9	852.9	514.1	143.3	126.3
Phenol	2.33	1.5	3	1.3	21.1	9.64	5.8	3.2	11.1	3.5	11.6	6.8
2,4-Dimethylphenol	-- ^d	--	--	0.96	1.31	--	0.0	--	0.0	2.6	0.7	0.0
Naphthalene	0.33	0.5	9.54	1.17	3.51	0.0077	0.8	1.1	35.4	3.2	1.9	0.0
Acenaphthylene	--	--	0.015	--	--	--	0.0	0.0	0.1	0.0	0.0	0.0
Acenaphthene	--	--	0.034	0.054	--	--	0.0	0.0	0.1	0.1	0.0	0.0
Fluorene	0.33	--	0.3	0.063	0.23	--	0.8	0.0	1.1	0.2	0.1	0.0
Phenanthrene	0.33	0.5	0.86	0.12	2.2	--	0.8	1.1	3.2	0.3	1.2	0.0
Anthracene	--	--	0.0078	0.048	--	--	0.0	0.0	0.0	0.1	0.0	0.0
LPAH	0.99	1	10.7568	1.455	--	--	2.5	2.2	39.9	3.9	0.0	0.0
Fluoranthene	0.33	1	0.3	0.11	--	--	0.8	2.2	1.1	0.3	0.0	0.0
Pyrene	0.33	1	0.32	0.11	--	--	0.8	2.2	1.2	0.3	0.0	0.0
Chrysene	0.33	--	0.43	0.21	--	--	0.8	0.0	1.6	0.6	0.0	0.0
Benzo(a)anthracene	0.33	--	0.097	0.21	--	--	0.8	0.0	0.4	0.6	0.0	0.0
Benzo(b)fluoranthene	--	--	0.048	0.079	--	--	0.0	0.0	0.2	0.2	0.0	0.0
Benzo(k)fluoranthene	--	--	0.048	0.083	--	--	0.0	0.0	0.2	0.2	0.0	0.0
Benzo(a)pyrene	--	--	0.023	0.047	--	--	0.0	0.0	0.1	0.1	0.0	0.0
Dibenzo(a-h)anthracene	--	--	--	--	--	--	0.0	0.0	0.0	0.0	0.0	0.0
Indeno(1,2,3,c-d)pyrene	0.67	--	--	--	--	--	1.7	0.0	0.0	0.0	0.0	0.0
Benzo(g,h,i)perylene	0.67	--	--	--	--	--	1.7	0.0	0.0	0.0	0.0	0.0
HPAH	2.66	2	1.266	0.849	--	--	6.7	4.3	4.7	2.3	0.0	0.0
PCBs	--	--	0.35	0.98	--	0.25	0.0	0.0	1.3	2.7	0.0	0.2
Dimethyl phthalate	--	--	0.17	0.07	0.23	--	0.0	0.0	0.6	0.2	0.1	0.0
Diethyl phthalate	--	--	3.07	0.63	5.34	3.62	0.0	0.0	11.4	1.7	2.9	2.5
Di-n-butyl phthalate	20.2	12.5	18.5	16.8	39.4	25.4	50.6	26.9	68.6	45.5	21.7	17.8
Benzyl butyl phthalate	9.74	12	83.1	46	36.6	25.6	24.4	25.9	308.2	124.5	20.2	18.0
Di-octyl phthalate	3.33	2	30.8	11.2	19.8	39.5	8.3	4.3	114.2	30.3	10.9	27.7
Total phthalates	33.27	26.5	135.64	74.7	101.37	94.12	83.4	57.1	503.0	202.1	55.9	66.0

TABLE 2-2. (Continued)

	Mean Concentration (ug/L)						Estimated Load ^b (lb/yr)					
	Michigan ^b (W039)	Lander ^b (W030)	Denny Way ^b (W027)	Hanford ^b (W032)	Harbor ^c (W037)	King ^c (W028)	Michigan (W039)	Lander (W030)	Denny Way (W027)	Hanford (W032)	Harbor (W037)	King (W028)
Methylene chloride	121	25.4	50	54.5	28.2	7.62	303.2	54.7	185.4	147.5	15.5	5.3
Chloroform	3.59	3.33	4.88	2.23	5.25	7.86	9.0	7.2	18.1	6.0	2.9	5.5
1,1,1-Trichloroethane	1.57	1.33	1.5	2.74	--	--	3.9	2.9	5.6	7.4	0.0	0.0
Trichloroethylene	5.67	98.7	1	1.25	3.64	0.31	14.2	212.7	3.7	3.4	2.0	0.2
Tetrachloroethylene	15.2	2.33	5.5	1.5	181	0.78	38.1	5.0	20.4	4.1	99.8	0.5
Benzene	1	1.33	0.5	1	2.2	2.53	2.5	2.9	1.9	2.7	1.2	1.8
Ethyl benzene	2.67	2.37	11.5	2	1.88	1.79	6.7	5.1	42.6	5.4	1.0	1.3
Toluene	16.7	7.34	164	11.1	5.06	4.17	41.8	15.8	608.1	30.0	2.8	2.9
1,3-Dichlorobenzene	--	--	0.015	--	7.85	0.23	0.0	0.0	0.1	0.0	4.3	0.2
1,2-Dichlorobenzene	--	--	0.83	--	7.62	0.077	0.0	0.0	3.1	0.0	4.2	0.1
1,4-Dichlorobenzene	--	--	14.8	4.2	0.46	0.15	0.0	0.0	54.9	11.4	0.3	0.1
1,2,4-Trichlorobenzene	--	--	0.025	--	--	5.38	0.0	0.0	0.1	0.0	0.0	3.8

^a Load calculated based on mean concentration and estimated total annual discharge from CSO.

^b Contaminant concentrations based on four overflow events.

^c Contaminant concentrations based on 13-18 nonoverflow sampling events.

^d -- = Undetected values.

Reference: Metro (1984).

2.3 STORM DRAINS

Stormwater runoff is typically considered a nonpoint source of pollution, even though it is usually collected and routed to nearby surface waters for disposal via ditches and pipes (i.e., point source discharges). Nonpoint surface water pollution is generated when storm water comes into contact with pollutants that have accumulated on the land surface. Stormwater runoff contamination is generally related to land use in the drainage basin. Sources of pollutants in urban stormwater runoff can be categorized as atmospheric deposition (e.g., industrial stack emissions, exposed material storage areas, unpaved roads and parking lots, construction and demolition sites, automobile emissions, and landfill operations), chemical spills, waste and chemical storage and handling practices, refuse deposition in streets, and urban erosion.

The project area is served by a combination of city and private storm drains. Private storm drains generally serve areas immediately adjacent to the waterways and are located predominately in the industrial areas along the Duwamish River and East and West Waterways. Because private storm drains are installed by individual property owners, they typically serve relatively small drainage basins (i.e., <5 ac). Locations of many of the private storm drains in the Elliott Bay project area are unknown. Locations of the private storm drains shown in Figure 1-2 were determined from maps obtained from the Port of Seattle, Lockheed Shipbuilding Co., Todd Shipyards Corp., and ARCO.

The city drains serve the larger metropolitan Seattle area. Drainage basins served by city storm drains in the project area range in size from 4 to 1,400 ac. The locations of city storm drains and their drainage basin boundaries are shown in Map 3 (see Map Appendix). Storm drain basin maps were generated using city drainage plans (1:2,400 scale), which show drainage system layout as well as topography, and King County drainage maps for areas outside the city limits.

Storm drain discharge can be estimated from the size and land use of the contributing area, and the mean annual precipitation for the Seattle

area (36 in). Flow estimates were calculated for city storm drains (Table 2-3) based on the total stormwater input to each basin, adjusted for specific land use and cover in that basin. Land use was separated into three main categories: residential, industrial, and undeveloped or park. The I-5 corridor, which drains to the Diagonal Way CSO/SD (111), and the I-5 storm drain were classified in a separate subcategory. The runoff coefficients used in the flow calculations for different land uses are listed below (Clark et al. 1977):

<u>Land Use</u>	<u>Runoff Coefficients</u>
Residential	
Separate storm sewer	0.20
Partially separated	0.15
Industrial	0.90
Undeveloped	0.05
I-5	0.95

Storm drain flow estimates range between 3 and 430 Mgal/yr, which are generally comparable to CSO discharges.

Pollutant loading information is unavailable for storm drains in the Elliott Bay project area. Approximate loading values for major storm drains were extrapolated using stormwater runoff data from nearby areas in Seattle and Bellevue and the estimated annual discharge from the city drains. These loading estimates were provided in Tetra Tech (1986b).

2.4 INDUSTRIAL FACILITIES

NPDES-permitted facilities located in the Elliott Bay project area are summarized in Table 2-4. Most of the industrial discharges consist of noncontact cooling water or storm water. There are no current permitted discharges of industrial process wastewater to the waterways in the project area. Some unpermitted discharges of industrial waste have been identified and are the subject of action by Ecology. There are likely other dischargers of process wastewater in the project area.

TABLE 2-3. ESTIMATED ANNUAL DISCHARGES FROM
CITY STORM DRAINS IN THE PROJECT AREA

Storm Drain	Area (ac)	Flow Rate (Mgal/yr)
Alki		
56th Ave. SW SD	655	100
SW Bronson	40	6
Fairmount SW	180	30
SW Ferry	10	2
SW Atlantic	20	3
SW California	125	20
Magnolia		
W. Glenmount	65	10
W. Bertona	40	6
W. Dravus	9	1
W. Raye	110	20
32nd W.	380	60
South Seattle Waterfront		
Pier 91 SD ^a	130	80
Interbay CSO/SD (068)	180	110
North Harbor Island		
11th Ave. SW CSO/SD (077)	37	30
Longfellow Creek	120	100
East Waterway		
SW Florida SD (36 in)	25	20
SW Lander SD (15 in)	8	7
SW Hanford CSO/SD (162)	70	60
SW Spokane CSO/SD (163)	4	3
S.Hinds CSO/SD (107)	50	40
West Waterway		
SW Florida CSO/SD (098)	25	20
SW Hinds CSO/SD (099)	1,410	280
SW Spokane CSO/SD (162)	19	20
16th Ave. SW CSO/SD (104)	12	10
SW Lander CSO/SD (105)	54	50
SW Lander SD (21 in)	9	8
SW Florida SD CSO/SD (106)	40	30
Kellogg Island		
SW Dakota SD	25	20
SW Idaho SD	390	60
Diagonal Ave SD	12	10
Diagonal Way CSO/SD (111)	1,030	430
Nevada SD	26	20
Upper Duwamish Estuary		
Duwamish SD ^b	10	10
SW Graham SD	170	20
SW Michigan SD	460	80
2nd Ave. S SD	240	150
S. 96th SD ^c	1,380	350
Slip 4 SD	170	150
Slip 4 CSO/SD (117)	150	140
I5 SD	29	10
Fox S. CSO/SD (116)	32	30
Slip 6 SD	120	100
S.River SD	9	8
Isaacson CSO/SD (156)	290	270
16th Ave. S. SD	12	10
Totals	7,403	2,836

^a Runoff coefficient estimated at 0.6.

^b Drainage basin area estimated at 20 ac with
runoff coefficient of 0.8.

^c Runoff coefficient estimated at 0.25.

TABLE 2-4. ELLIOTT BAY NPDES-PERMITTED FACILITIES

Facility Name	Permit Number	Type of Industry	Discharge Type	Flow Rate (gal/day)	NPDES Expiration Date
Alki Treatment Plant	WA-002901-7	Municipal wastewater plant	Primary effluent	NA ^a	1991
Advance Electroplating	WA-000172-4(I)	Metal finishing	NA	103,000	Cancelled
Airco Welding	WA-002902-5(I)	Acetylene gas manufacture	Noncontact	4,500	1988
ARCO	WA-002969-6(I)	Bulk petroleum storage	Surface runoff	NA	1989
Ash Grove/Kaiser	WA-000225-9(I)	Cement receiving, storage, distribution	Truck wash, noncontact	52,000	1982
Ash Grove/Lone Star	5162	Cement manufacture	Truck rinse, cool water	NA	1989
Boeing AWACS	WA-003036-8(I)	Airborne electronic checkout	Noncontact	155,000 max	1986
Boeing-Develop. Center	WA-000351-4	Mfg. aircraft, aerospace hardware	Noncontact, runoff	NA	NA
Boeing-EMF Electron Mfg Fac	WA-003071-6(I)	Electronic mfg & assembly	Noncontact	12,500	Cancelled
Boeing North Field	WA-000086-8(M)	Aircraft testing	Noncontact (George flume)	150,000	1986
Boeing Plant 2	WA-000291-7(I)	Aircraft parts manufacture	Noncontact-28 outfalls	1,070,500 total	1986
Boeing Scien. Res. Center	WA-002987-4(I)	Research and training center	Noncontact-4 outfalls	16,200	1987
Boeing-Thompson	WA-003065-1(I)	Assembly, fatigue test	Noncontact cooling	16,000 max	1987
City of Seattle	WA-000328-0(I)	Georgetown steamplant	NA	50 ft ³ /sec	Cancelled
Columbia Cement	WA-000185-6(I)	Cement distribution	Noncontact, truck wash	26,000	1986
Duamish Shipyard	WA-003093-7(I)	Ship construction and repair	Drydock, marine railway, ballast/ bilge water, high press water, runoff, noncontact	NA	Draft permit
Fisher Mills	WA-002135-1	Flour milling	Groundwater, noncontact	75,500 max	1991
GATX	WA-002214-4(I)	Bulk petroleum storage	Surface runoff	NA	1988
Ideal Basic	WA-000223-2	Cement manufacture	Noncontact	24,000 max	1990
Earle M. Jorgenson	WA-003078-3(I)	Mfg. ingots, custom machined parts	Vacuum degreaser effluent, noncontact	200,000 80,000 noncontact	1990
Kaiser/Lone Star	WA-000224-1(I)	Cement manufacture	Noncontact	5,000	1977
Kenworth	WA-003079-1	Truck fabrication, assembly	Noncontact	163,500 max	1991
Liquid Air	WA-003076-7(I)	Industrial gas manufacture	Noncontact (emerg)	18,000 max	1988
Lockheed Plant 1	WA-000055-8	Ship construction	NA	120,000	1980
Lockheed Plant 2	WA-000055-8	Ship fitting, repair	NA	14,440 ft ³ /day	1980
Marine Power & Equip	WA-003089-9	Ship building, repair, conversion	Flooding drydock	236,000 ft ³ /dock	1992
Merlino Construction	WA-003092-5	Contractor for road, utility construction	Runoff, steam cleaning discharge	7,200	1992
Mobil	WA-002900-9(I)	Bulk petroleum storage, distrib.	Surface runoff	NA	1987
Rhone-Poulenc (Monsanto)	WA-000309-3(I)	Vanillin production	Noncontact	100,000	1986
North Coast Chemical	WA-002912-2(I)	Chemical compounding	Noncontact	1,000	1987
Northwestern Glass-Incon	WA-000343-3	Glass container manufacture	Noncontact	38,000	1990
Ocean Construction	WA-003094-5(I)	Cement manufacture	Runoff	158,400	1993
Port of Seattle (Terminal 30)	WA-000127-9(I)	Container terminal	Rischarge from product recovery system at old Chevron facility (emergency)	NA	1989
Renton Treatment Plant	WA-002958-1(M)	Municipal treatment plant	Secondary effluent	NA	1992

TABLE 2-4. (Continued)

Facility Name	Permit Number	Type of Industry	Discharge Type	Flow Rate (gal/day)	NPDES Expiration Date
Seaboard Lumber	WA-002230-6(I)	Sawmill	Noncontact	10,800	Cancelled 1984
Seafab/Quemetco	WA-000143-1(I)	Fabricates lead products, mfgs lead oxide	Noncontact, floor/roof drain, laundry	NA	NA
Seattle Rendering	WA-000162-7	Animal waste rendering	Surface runoff	0.2 ft ³ /s	1992
Seattle Steam-Western	WA-000150-3(I)	Steam production	Cooling water	60,000	1984
Seattle Steam-Post	WA-000159-7(I)	Discharges to sanitary sewer	Permit cancellation pending	NA	NA
Seattle Steel	WA-000074-4	Hot forming steel manufacture	Cooling pond overflow	979,300 max	1988
Shell Oil	WA-00308-5(I)	Bulk petroleum storage, distrib.	Treated storm water, tank drawdown	NA	1985
Texaco	WA-000179-1(I)	Bulk petroleum storage, distrib.	Surface runoff	NA	1988
Time-DC	WA-002172-5(I)	Motor freight common carrier	Runoff	22,000,000 max	1984
Todd Shipyard	WA-000261-5(I)	Shipyard	Noncontact	66,000 max	1987
West Point Treatment Plant	WA-002918-1	Municipal wastewater plant	Primary effluent	195,000,000 (monthly average)	1977
Widing Transportation	Permit being drafted	--	--	--	--

^a NA = Not available.

Metro has issued industrial pretreatment permits to 114 facilities in the project area. However, Metro considers only 41 of the facilities as major dischargers (Hildebrand, D., 23 December 1987, personal communication), and they are monitored periodically by Metro to determine compliance with permit conditions. All 114 of the permitted facilities are listed in Table C-1 (Appendix C) along with the CSO basin in which they are located. The 41 major facilities and the analytical constituents that are monitored from each facility are summarized in Table C-2 (Appendix C). Wastewater from these facilities would only be discharged to the project area waterways during overflow conditions. It is expected that the large diluting flows from stormwater runoff would mask any effects from these intermittent industrial discharges.

Other potential sources in the project area were identified based on information compiled from Ecology, U.S. EPA, Metro, Port of Seattle, and other available literature on Elliott Bay. These potential sources include sites that were identified on Ecology's Hazardous Waste Cleanup List (WEC Alert! 1987), sites that were inspected by the Elliott Bay Action Team (Ecology 1987), sites that were identified on U.S. EPA's list of potential hazardous waste sites that are currently under investigation in the Comprehensive Environmental Response, Compensation, and Liability Information System, (CERCLIS) (U.S. EPA, 22 October 1987, personal communication), problem sites identified during Metro's Industrial Non-Point Source Investigations (Metro 1985), and sites that were identified as potential problems in published reports on the area. Locations of potential contaminant sources in the Elliott Bay project area are shown in Map 4 (see Map Appendix). The key to the map (Table B-1) and references for that map are presented in Appendix B.

Map 4 can be used in conjunction with the CSO and storm drain basin maps (Maps 1-3 in Map Appendix) to determine which storm drain or CSO might be affected by each of these potential sources. It was beyond the scope of this study to verify the drainage basin boundary maps. Field verification would require detailed field inspections of the drainage system layout and individual properties to determine discharge pathways. Therefore, there is some uncertainty of the pathways that the contaminants might travel to area

waterways from some of the potential problem sites, particularly for those that are located near a drainage basin boundary line.

2.5 GROUNDWATER

Groundwater may contribute contaminants to the waterways in the Elliott Bay project area. Groundwater contamination may occur as a result of improper waste disposal practices and accidental spills of chemicals or petroleum products. Although data are limited, available information indicates that the following specific sites have potential for groundwater contamination:

- Abandoned landfills (Seattle-King County Department of Public Health 1984)
 - Interbay landfill - approximately 55 ac located between Magnolia and Queen Anne
 - West Seattle landfill - approximately 20 ac located east of Harbor Ave. SW and south of SW Florida St.
 - South Park landfill - approximately 96 ac located between W. Marginal Way and 2nd Ave. S., north of Sullivan St. and south of Kenyon St.
- Active bulk petroleum storage facilities
 - Tank farms on Harbor Island and south Seattle (Ryan, C., 6 July 1987, personal communication)
 - Chemical Processors, Inc., Pier 91 facility (Tetra Tech 1988f)
 - GATX, 1773 Alaskan Way S.

- Inactive bulk petroleum storage facilities
 - Terminal 30 (removed; GeoEngineers 1987)
 - Unocal, 3131 Elliott (Cargill, D., 25 February 1988, personal communication)
 - Terminal 18, old Shell Oil Company facility
 - Terminal 91 naval fuel and bunkering facility (Hotchkiss, D., 22 December 1987, personal communication).
- Industrial sites (Cargill, D., 19 August 1988, personal communication)
 - Wyckoff, West Seattle, 2801 SW Florida St.
 - Kenworth Trucking, 8801 E. Marginal Way S.
 - Northwest Cooperage, 7152 1st Ave. S.
 - Sternoff Metals, 2230 4th Ave. S.
 - Longview Fiber, 5901 E. Marginal Way S.

Other sites in the project area where groundwater contamination may exist have been identified by Sweet-Edwards & Associates and Harper-Owes (1985). Available information is not adequate to characterize contaminant conditions or determine loadings from groundwater to the project area.

2.6 ATMOSPHERIC DEPOSITION

Atmospheric deposition occurs both on the land and water surfaces in the Elliott Bay project area. Contaminants contained in the fraction deposited on the land are transported to the waterways via surface water runoff, and are therefore associated with storm drain and CSO discharges in

the project area. The total surface area of Elliott Bay is 8 mi² compared to 26 mi² of land surface in the basin. Therefore, the amount of contaminants deposited directly on the water surface within the project area is considered negligible compared with the contribution from urban runoff.

According to Puget Sound Air Pollution Control Agency (PSAPCA) records for 1982 (PSAPCA 1983b), total suspended particulate matter (TSPM) emissions from the 32 sources monitored in the project area were 1,355 ton/yr. Contaminants deposited directly on the waterways were calculated based on the following assumptions:

- Eighty percent of the TSPM emitted from industries in the project area is deposited within the project boundaries
- Particulates are distributed proportionately over the water and land surfaces
- Composition of TSPM is similar to street dust.

The total metals loading to the waterways from atmospheric deposition (sum of arsenic, cadmium, chromium, copper, lead, nickel, and zinc) is about 0.3 ton/yr and the total PAH loading is about 0.002 ton/yr. These values are negligible compared with other source inputs in the project area.

Although the total loading of contaminants via atmospheric deposition is considered negligible relative to loadings from other sources in the project area, deposition of gaseous air pollutants and particulate-bound metals and organic compounds in the sea-surface microlayer (upper 50 um of sea surface) may have considerable environmental significance. The sea-surface microlayer is an important biological habitat, especially for the reproductive stages of many fish and shellfish. Recent studies in Puget Sound have demonstrated enrichment of particulate materials and dissolved organic compounds in the microlayer (e.g, Word and Ebbesmeyer 1984; Hardy and Antrim 1988).

2.7 SPILLS

Information on accidental spills on land and water in the area is limited. Ecology maintains a file on spill complaints reported by private citizens. These reports usually contain information on the date and location of the spill, a description of what and how much was spilled, and the cleanup measures taken. Typically, there is insufficient information available to calculate contaminant loadings.

Metro maintains chronological files on trouble calls (i.e., mainly pertaining to spills and fish kills) in the Elliott Bay system. These trouble call reports have been used by Metro and other agencies to identify sources of toxic contaminants to storm drains discharging to Elliott Bay and the Duwamish River.

The U.S. Coast Guard also maintains a file on marine spills. Spills are recorded for the project area beginning in 1973. Spill information includes the date, location, type of material, and estimated quantity spilled. The reported spills consisted primarily of petroleum products (i.e., gasoline, diesel, fuel oil, jet fuel, and waste oil). However, because the location is given by latitude and longitude to the nearest minute, it is impossible to determine the exact location of the spill. Also, because there is no information on the amount of spilled material recovered from cleanup operations, it is not possible to evaluate total loading of contaminants to the Elliott Bay project area.

3.0 METHODS

The techniques used to collect drain samples and the approach used to select problem drains and link potential sources to offshore problem areas are described below.

3.1 SOURCE EVALUATION APPROACH

Problem sources were identified based on the contaminant concentrations measured in the sediments collected from these drains (i.e., CSOs and storm drains), and on comparisons between the contaminants found in sediments in the drains and the contaminants that were found in the offshore receiving environment problem areas (PTI and Tetra Tech 1988). The inter-drain comparisons were conducted using the results of the Elliott Bay Action Program sampling program, which focused on the combined sewer overflows and storm drains discharging into the project area. The source to receiving environment comparisons were based on the Elliott Bay Action Program drain and receiving environment sediment data, historical data (e.g., Metro 1985; Sample 1987; Hubbard and Sample 1988), and ancillary information obtained from agency files (see Section 2.0).

The identification and ranking of problem CSOs and storm drains followed the approach (Figure 3-1) described by Tetra Tech (1988g). This approach was consistent with the one used to identify problem areas in the receiving environment of Elliott Bay and the lower Duwamish River (PTI and Tetra Tech 1988). Problem chemicals in each drain were identified based on either of the following criteria:

- Exceedance of a highest AET value for chemicals where AET values have been derived

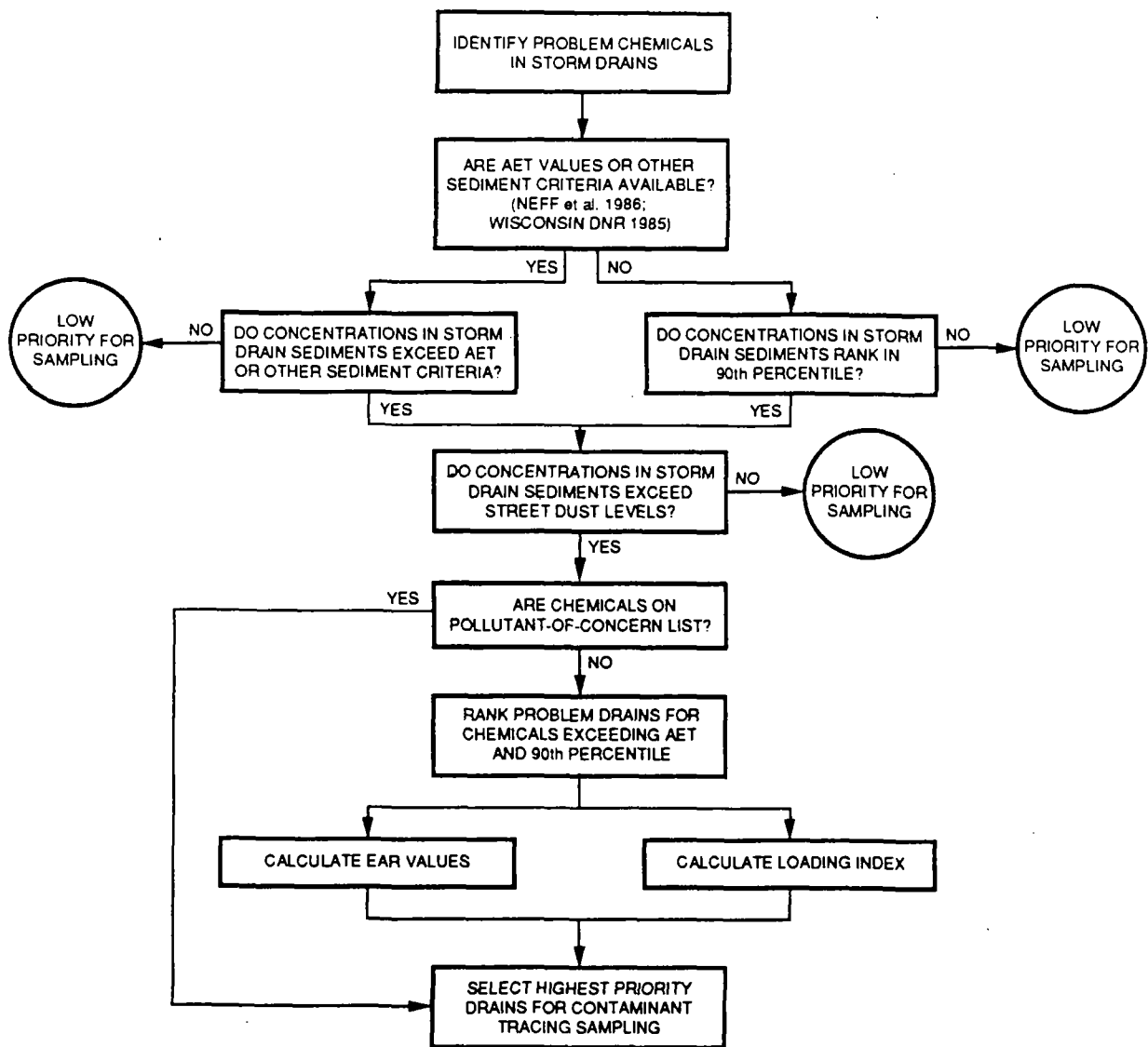


Figure 3-1. Decision criteria for selecting problem chemicals and ranking problem storm drains.

- Exceedance of the 90th percentile concentration (defines the concentration above which 10 percent of the observations fall) measured during the source survey, for chemicals where there are no available AET values.

The focus of the AET approach is to identify concentrations of chemical contaminants in sediments that are associated with statistically significant biological effects (relative to reference conditions). The following biological indicators were used to develop AET values:

- Depression in abundances of major taxonomic groups of benthic infauna (e.g., Crustacea, Mollusca, Polychaeta)
- Amphipod mortality bioassay using Rhepoxynius abronius
- Oyster larvae abnormality bioassay using Crassostrea gigas
- Microtox bioluminescence bioassay using Photobacterium phosphoreum.

For a given chemical and a specific biological indicator, the AET is the concentration above which statistically significant biological effects occurred in all samples of sediments analyzed.

AET values have been proposed for 64 organic and inorganic toxic chemicals using synoptic chemical and biological data from 200 stations in Puget Sound (Tetra Tech 1987a). For each chemical, a separate AET was developed for each biological indicator listed above, resulting in four sets of AET values. A list of the HAET and LAET for each chemical is provided in Table 3-1.

Contaminants for which HAET values are unavailable were selected as problem chemicals based on the 90th percentile concentration (Table 3-2) measured in the source sampling program. Drains whose sediments exceeded a high AET value or a 90th percentile concentration for at least one chemical were identified as potential problem sources.

TABLE 3-1. PUGET SOUND AET VALUES
 (ug/kg dry weight = ppb for organic compounds;
 mg/kg dry weight = ppm for metals)

Chemical	Lowest AET	Highest AET
<u>LPAH</u>	5,200	6,100
Naphthalene	2,100	2,400
Acenaphthylene	560	640
Acenaphthene	500	980
Fluorene	540	1,800
Phenanthrene	1,500	5,400
Anthracene	960	1,900
<u>HPAH</u>	12,000	38,000
Fluoranthene	1,700	9,800
Pyrene	2,600	11,000
Benzo(a)anthracene	1,300	4,500
Chrysene	1,400	6,700
Benzofluoranthenes	3,200	8,000
Benzo(a)pyrene	1,600	6,800
Indeno(1,2,3-c,d)pyrene	600	880
Dibenzo(a,h)anthracene	230	1,200
Benzo(g,h,i)perylene	670	5,400
<u>Total PCBs</u>	130	2,500
<u>Total chlorinated benzenes</u>	170	680
1,3-Dichlorobenzene	--	--
1,4-Dichlorobenzene	110	260
1,2-Dichlorobenzene	35	50
1,2,4-Trichlorobenzene	31	64
Hexachlorobenzene	70	230
<u>Total phthalates</u>	3,300	3,400
Dimethyl phthalate	71	160
Diethyl phthalate	--	200
Di-n-butyl phthalate	1,400	1,400
Butyl benzyl phthalate	63	470
Bis(2-ethylhexyl) phthalate	1,900	1,900
<u>Pesticides</u>		
p,p'-DDE	9	15
p,p'-DDD	2	43
p,p'-DDT	3.9	11

TABLE 3-1. (Continued)

Chemical	Lowest AET	Highest AET
<u>Phenols</u>		
Phenol	420	1,200
2-Methylphenol	63	63
4-Methylphenol	670	1,200
2,4-Dimethyl phenol	29	29
Pentachlorophenol	--	--
2-Methoxyphenol	930	930
<u>Miscellaneous extractables</u>		
Hexachlorobutadiene	120	290
1-Methylphenanthrene	310	370
2-Methylnaphthalene	670	670
Biphenyl	260	270
Dibenzothiophene	240	250
Dibenzofuran	540	540
Benzyl alcohol	57	73
Benzoic acid	650	650
n-Nitrosodiphenylamine	40	220
<u>Volatile organic compounds</u>		
Tetrachloroethene	140	140
Ethyl benzene	33	37
Total xylenes	100	120
<u>Metals</u>		
Antimony	3.2	26
Arsenic	85	700
Cadmium	5.8	9.6
Copper	310	800
Lead	300	700
Mercury	0.41	2.1
Nickel	28	49
Silver	5.2	5.2
Zinc	260	1,600

Reference: Tetra Tech (1987a).

TABLE 3-2. NINETIETH PERCENTILE CONCENTRATIONS FOR FREQUENTLY
DETECTED CONTAMINANTS WHERE HAETS ARE UNAVAILABLE

Chemical	90th Percentile Concentration ^a
Metals (mg/kg)	
Antimony	775
Chromium	797
Nickel	223
Selenium	2.6
Organic compounds (ug/kg)	
Indeno(1,2,3-c,d)pyrene	3,360
Di-n-octyl phthalate	7,515

^a 90th percentile calculated using all Elliott Bay Action Program
CSO and storm drain sampling data.

Problem drains were ranked based on the following criteria:

- Number of problem chemicals identified in each drain.
- Magnitude of exceedance of reference area sediment chemistry conditions. The EAR technique is a comparison of drain sediment data with offshore receiving environment sediment data collected from reference areas (i.e., noncontaminated areas). EAR values are calculated by dividing the measured concentration in the sediments collected from the drain by the reference concentration.
- Contaminant loading index for each drain. Loading indices are not true contaminant loading values, but can be used as an indication of loading potential. Loading indices are calculated as the product of the concentration of the contaminant measured in the drain sediments and the estimated average annual flow for each drain.

The approach used to link potential contaminant sources to contamination in the receiving environment sediments for the highest priority problem areas and stations was based on the following information:

- Proximity of sources to the problem area in the receiving environment
- Comparison of the available source sediment chemistry data from the Elliott Bay initial screening program and Metro's Industrial Non-Point Source Investigation (Metro 1985; Sample 1987; Hubbard and Sample 1988) with available offshore sediment data
- Known or suspected sources of contaminants discharging into a designated high-priority problem area in the receiving environment

- Spatial distribution of contaminants in the offshore sediments
- Past or ongoing practices that may contribute to the contamination observed in the receiving environment.

Contaminant sources (i.e., CSOs, storm drains, spills, groundwater inflow, and waterfront land-use activities) are expected to have greater effects on the areas immediately offshore. Therefore, the proximity of drain outfalls and waterfront facilities to the problem stations identified in the receiving environment was a major factor in the source evaluations.

The problem chemicals identified in the drains were also compared with the problem chemicals identified in the offshore sediments to determine whether a drain contributed to the contamination observed in the receiving environment. If the problem chemicals differed between the drain and the offshore sediments, that drain may not have been a major contributor to the contamination problem. However, the absence of an apparent relationship between the chemical contaminants measured in the drain and receiving environment sediments does not preclude the possibility of past contaminant contributions from that drain to the receiving environment.

To further characterize the relative influence that the particulates discharged from drains and waterfront activities had on the sediment chemistry in the offshore sediments, the relative percent distributions of chemical concentrations were used to compare both the offshore sediment samples and the drain sediments. A relative distribution was obtained by calculating percentage contributions (by concentration) of a particular chemical or compound within a related group of chemicals (e.g., HPAH, LPAH, or metals). Plots of the relative distributions were used to compare source sediment samples with offshore sediment samples. The relative distributions of compounds can also be compared between samples without having to normalize the data to account for differences in the physical characteristics of each sample (i.e., grain size and organic carbon content).

Evaluation of the spatial distribution of contaminants in the offshore sediments aids in the identification of sources. For example, widespread contamination in the offshore sediments suggests that there may be multiple sources contributing to the contamination. In addition, concentration gradients are frequently apparent in the offshore sediments that point toward a particular source or sources.

Information obtained from agencies familiar with the past or ongoing practices at industries in the area can also be used as evidence to link sources to the problem areas in the receiving environment. Information on industrial practices in the project area has been obtained from Ecology, U.S. EPA, Metro, and the Port of Seattle.

Dredging will affect the distributions of contaminants in the offshore sediments. Therefore, dredging was considered in the evaluation of the spatial distribution of contaminants in the problem areas identified in the receiving environment sediment samples. Dredging information compiled for the Elliott Bay project area is presented in Appendix G.

The highest priority drains and the sources linked to the highest priority problem areas and stations identified in the offshore receiving environment (PTI and Tetra Tech 1988) are targeted for additional contaminant tracing and source identification activities.

3.2 SOURCE SAMPLING APPROACH

CSOs and storm drains were targeted because they constitute the largest category of ongoing sources in the project area. There are no direct discharges of industrial process wastewater to the waterways. NPDES-permitted discharges in the project area consist entirely of noncontact cooling water and stormwater runoff. Process wastewater from industrial facilities in the project area are generally discharged to the sanitary sewer system and treated at the West Point municipal wastewater treatment plants prior to discharge to the waterways. In addition, the CSOs and city storm drain system collect stormwater runoff from the majority of the land

surface in the project drainage basin, and therefore, also incorporate most of the nonpoint discharges (i.e., surface runoff) from the project area.

Direct discharges of waste materials and stormwater runoff from properties immediately adjacent to the waterways were not sampled during the Elliott Bay source sampling program. Sampling of these potential sources and other nonpoint sources, such as groundwater inflow were beyond the scope of this investigation due to 1) the difficulty in obtaining access to private property, 2) the lack of information on these potential sources at the time the sampling plan was designed, 3) the large number of private storm drains in the project area (there are approximately 100 private drains on Harbor Island alone), and 4) the expected low level of contaminant loading from most private storm drains, which serve relatively small drainage areas (it is recognized that some small drains are highly contaminated and may be significant contributors to offshore contamination).

A source sampling plan was initially designed to screen a large number of drains (i.e., CSOs and storm drains) for a wide variety of potential contaminants. The sampling plan used a technique originally developed by Metro (Metro 1985) in which contaminants are traced to their ultimate sources through the collection and chemical analysis of in-line sediment samples from individual drains (Sample 1987; Hubbard and Sample 1988). However, because the Elliott Bay source sampling program was designed as an initial screening investigation, single sediment samples were collected only from a single manhole located near the mouth of each drain. Samples collected from the downstream end of each drain provide a chemical characterization of sediments composited from the entire drainage basin or service area. Based on the results of the initial screening, each drain can be evaluated and prioritized for additional contaminant tracing and source identification activities. This approach is expected to reduce the number of samples required for source identification by eliminating noncontaminated drains from further investigation. The results of the Elliott Bay drain sampling program have been used to recommend drains for additional investigation, and were also used to design a stormwater sediment sampling plan for the Superfund remedial investigation on Harbor Island (Tetra Tech 1988d).

Contaminant tracing activities are reserved for future investigations of specific problem drains.

3.2.1 Station Locations

Sediment samples were collected from 7 CSOs, 20 storm drains, and 15 CSO/SDs that discharge into in the project area (Figure 3-2). In some cases, the city and Metro route the overflows from the combined sewer system to area waterways via an existing storm drain system. These outfalls are designated as CSO/SDs for the purposes of this report.

With the exception of the I-5 SD, Fox S. CSO/SD (116), and Diagonal Way CSO/SD (111), all drains were sampled at a single station located near the mouth of the drain. The I-5 SD was sampled at two locations, a manhole near the mouth (MH1) and a manhole above the tidally influenced portion of the drain (MH2), to evaluate the effects of tidal interferences on the distribution of contaminants in the drain sediments. The I-5 SD was selected for this evaluation because it is the only drain in the project area where land-use characteristics (i.e., highway) were homogeneous throughout most of the basin.

The Fox S. CSO/SD (116) was sampled at three locations, because samples previously analyzed by Metro (Sample, T., 23 October 1987, personal communication) indicated that contaminants found in the drain were largely from the lower portion of the basin occupied by Marine Power and Equipment. Sampling stations on the Fox S. CSO/SD (116) were located at 1) the manhole near the entrance to Marine Power and Equipment (MH3), 2) the manhole midway across the Marine Power and Equipment property (MH2), and 3) the manhole located near the mouth of the drain (MH1).

The Diagonal Way CSO/SD (111) was sampled at two locations to evaluate the difference in contaminant distributions in sediments collected from a manhole vs. sediments collected from within the drain pipe. The Diagonal Way CSO/SD was selected for this evaluation, because the diameter of the drain at the downstream end of the system (144 in) was large enough to enter and collect sediment samples. Samples were collected from a manhole (MH1)

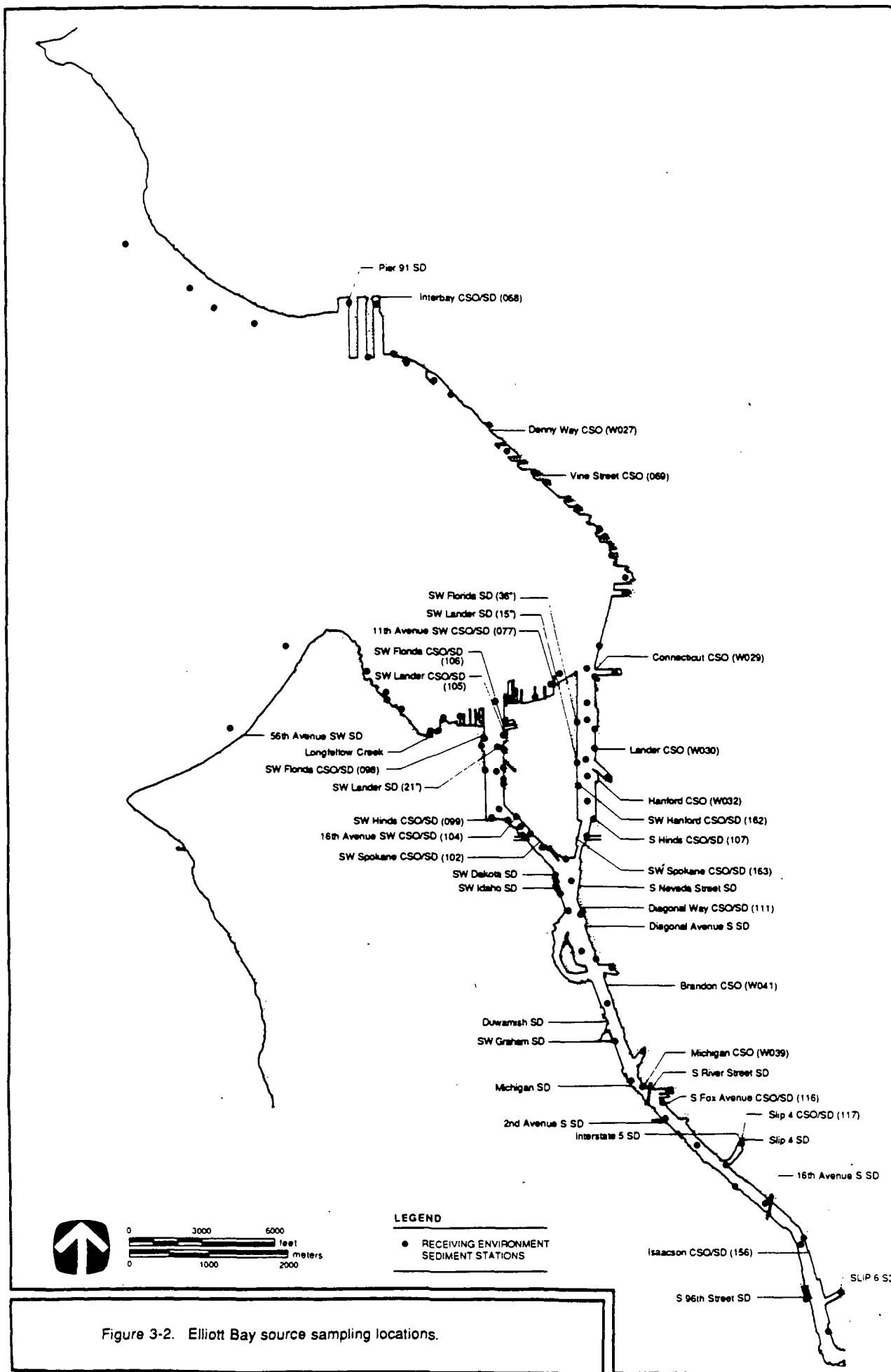


Figure 3-2. Elliott Bay source sampling locations.

and from a station in the pipe approximately 25 ft upstream of the manhole (MH1U).

3.2.2 Sample Collection

The Elliott Bay source sampling program was conducted between 23 September and 17 October 1985. The sampling effort was preceded by 2 mo of below normal precipitation. Rainfall from the National Weather Service station on Portage Bay in Seattle for July (0.22 in) was 0.67 in below normal, and for August (0.72 in) was 0.66 in below normal (National Climatic Data Center 1985). Low rainfall during the sampling program aided the sampling effort by allowing access to the drains for sediment sample collection and by minimizing disturbances of drain sediment deposits.

Sediment samples were collected during periods of low tide to allow access to tidally influenced manholes. Adjustments were made to the original sampling plan because of difficulties in obtaining sediment samples from several drains. Sediment deposits were not found in several CSOs and in storm drains located on steeply sloped hillsides. The following CSOs and storm drains were inspected, but not sampled because of insufficient sediment deposits in the manholes:

- Magnolia CSO (W006)
- 32nd Ave. SW SD
- University CSO (070)
- Madison CSOs (071,164)
- King CSO (W028)
- S. Massachusetts SD
- S. Stacy SD

- SW Spokane SDs
- Chelan CSO (W036)
- Fairmount SW SD.

In all, 56 drain stations were inspected during the Elliott Bay sampling effort. A summary of the source stations that were investigated and a description of the samples collected is presented in Appendix E.

Samples were collected from sediment deposits in the manhole or pipes in each drain line using stainless steel scoops and spoons. Separate subsamples for volatile organic analyses were collected in duplicate 40-cm³ glass vials while in the manhole. Samples for the remaining chemical and physical analyses were placed in a precleaned stainless steel bucket and brought to the surface of the manhole prior to filling sample containers. This procedure minimized the time that the sampling personnel were in the manhole. Samples were homogenized and placed in the following containers for analyses:

- 500 cm³ of sample were transferred to a precleaned glass jar with a polytetrafluoroethane (PTFE) cap liner for analysis of extractable organic compounds
- 125 cm³ of sample were transferred to a precleaned glass jar for metals analysis
- 100 cm³ of sample were transferred to a freon-rinsed glass jar for oil and grease analysis
- 100 cm³ of sample were transferred to a resealable plastic bag for grain-size analysis.

3.2.3 Chemical Analyses

Sediment samples were analyzed for the chemicals listed in Table 3-3. Most of the chemical contaminants analyzed for under the Elliott Bay Action Program have at least one of two properties 1) they bioaccumulate, possibly with adverse biological effects in the food chain, or 2) they produce adverse biological effects even when not bioaccumulated. U.S. EPA priority pollutants that may be currently or historically discharged into the project area are included on the list (see Table 3-3). Compounds not on the U.S. EPA list of priority pollutants have also been considered on the basis of their local presence.

The target contaminants measured during the source sampling effort are identical to those contaminants analyzed for in the offshore sediments (PTI and Tetra Tech 1988), which facilitated comparisons between variables measured in the two sampling environments. Analytical procedures specified in Puget Sound Estuary Program (PSEP) protocols (Tetra Tech 1986c) were used to analyze chemical constituents in the drain and receiving environment sediments. The PSEP protocols were developed to promote the use of acceptable and comparable methods when measuring contaminants in Puget Sound. In addition, the protocols provide guidelines to assess the quality of data obtained from different laboratories or analytical techniques.

Metals--

The following 11 of the 13 U.S. EPA priority pollutant metals were analyzed for in the 48 drain sediment samples collected in this study: antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. The remaining two priority pollutant metals, beryllium and thallium, were not analyzed because historical data did not suggest that these metals were of concern in the project area. Iron and manganese were also analyzed.

Samples were prepared by thawing the frozen sediment, homogenizing, freeze-drying, and grinding each sample. The sample was then either subjected to a total acid digestion for atomic absorption (AA) analysis, or

TABLE 3-3. LIST OF CONTAMINANTS AND CONVENTIONAL
VARIABLES ANALYZED DURING THE ELLIOTT BAY ACTION PROGRAM

Low molecular weight PAH	Phenols
naphthalene	phenol
acenaphthylene	2-methylphenol
acenaphthene	4-methylphenol
fluorene	2,4-dimethylphenol
phenanthrene	2-chlorophenol
anthracene	2,4-dichlorophenol
	4-chloro-3-methylphenol
High molecular weight PAH	2,4,6-trichlorophenol
fluoranthene	2,4,5-trichlorophenol
pyrene	pentachlorophenol (PCP)
benz(a)anthracene	
chrysene	Miscellaneous extractable
benzofluoranthenes	compounds
benzo(a)pyrene	1-methylphenanthrene ^a
indeno(1,2,3-c,d)pyrene	2-methylphenanthrene ^a
dibenzo(a,h)anthracene	3-methylphenanthrene ^a
benzo(g,h,i)perylene	2-methylnaphthalene
	biphenyl ^a
Total PCBs	dibenzofuran
	benzyl alcohol
Neutral halogenated compounds	benzoic acid
1,2-dichlorobenzene	carbazole ^a
1,3-dichlorobenzene	coprostanol ^a
1,4-dichlorobenzene	isophorone
1,2,4-trichlorobenzene	
hexachlorobenzene (HCB)	Volatile organic compounds
2-chloronaphthalene	benzene
hexachlorobutadiene	bromodichloromethane
	bromoform
Phthalate esters	bromomethane
dimethyl phthalate	carbon tetrachloride
butyl benzyl phthalate	chlorobenzene
di-n-octyl phthalate	chloroethane
	chloroform
Pesticides	chloromethane
p,p'-DDE	dibromochloromethane
p,p'-DDD	1,1-dichloroethane
p,p'-DDT	1,2-dichloroethane
aldrin	1,1-dichloroethene
chlordane	trans-1,2-dichloroethene
dieldrin	1,2-dichloropropane
endrin	cis-1,3-dichloropropene
endrin aldehyde	trans-1,3-dichloropropene
heptachlor	ethylbenzene
alpha-HCH	1,1,2,2-tetrachloroethane
beta-HCH	tetrachloroethene
delta-HCH	1,1,2-trichloroethane
gamma-HCH (lindane)	trichloroethene
	toluene

TABLE 3-3. (Continued)

total xylenes	Conventional variables
vinyl chloride	total organic carbon
acrolein	total solids
acrylonitrile	percent fine-grained
2-chloroethylvinyl ether	material
	total nitrogen
	oil and grease
Metals	
antimony	
arsenic	
cadmium	
chromium	
copper	
iron	
lead	
manganese	
mercury	
nickel	
selenium	
silver	
zinc	

^a Tentatively identified organic compounds.

pressed into a pellet for x-ray fluorescence (XRF) analysis. Antimony, cadmium, mercury, selenium, and silver were quantified using AA analysis. XRF was used to quantify arsenic, chromium, copper, iron, manganese, nickel, lead, and zinc.

Extractable (Semivolatile) and Volatile Organic Compounds--

Analyses for 37 of the 57 U.S. EPA priority pollutant extractable organic compounds, 19 additional extractable compounds not listed as U.S. EPA priority pollutants, total PCBs, and 13 priority pollutant chlorinated pesticides were performed on all 48 sediment samples collected for this study. In addition, 30 volatile organic compounds were analyzed for in 21 of the 48 drain sediment samples. Priority pollutant bases and halogenated ethers were not included in the analyses, in accordance with recommendations of PSEP (Tetra Tech 1986c). These excluded compounds have been detected infrequently in Puget Sound studies. Gas chromatography/mass spectrometry (GC/MS) searches for 17 additional nonpriority pollutant compounds or compound classes (i.e., tentatively identified compounds) were also performed on all sediment extracts; these compounds were specified to the laboratory prior to analysis.

The isotope dilution GC/MS procedure used to analyze acid and neutral compounds was derived from Tetra Tech (1986c). Recovery corrections were applied to detection limits as well as to detected values to account for the effect of analytical losses on overall analytical sensitivity. Poor surrogate recoveries for a number of compounds (especially chlorinated benzenes and chlorinated phenols) resulted in high detection limits for these compounds.

Total PCBs and 13 pesticides were quantified using gas chromatography/electron capture detection (GC/ECD). Extraction and analytical procedures followed methods specified by the U.S. EPA Contract Laboratory Program (CLP) (U.S. EPA 1986a).

Analyses for 30 volatile organic compounds were performed on 21 of the 48 source sediment samples. Selection of drains for analysis of volatile

organic compounds was based on the visual appearance or odors noted in the drain. Laboratory analytical procedures for analysis of volatile organic compounds in Elliott Bay source sediments followed PSEP protocols (Tetra Tech 1986c), and are described in detail in Tetra Tech (1988a).

Ancillary Analyses--

Conventional variables measured in the source sediment samples included grain size, total solids, total volatile solids, total organic carbon (TOC), total nitrogen, and oil and grease (see Table 3-3).

All of the methods used to analyze conventional variables, except that used for analysis of grain size, followed the methods recommended in PSEP protocols (Tetra Tech 1986c). The PSEP method for grain-size analysis specifies that the sieves used in wet-sieving particles greater than 65 μm are to be dried after each use. This process allows particles less than 65 μm that adhere to the sieve surface to be removed and added to the sample fraction analyzed for percent silt and clay. However, only wet sieving was conducted for this sample set (Crecelius, E., 2 March 1987, personal communication). The consequences of not following the sieve drying and particle collection steps cannot be evaluated from the data. The initial weights of samples were not provided, and therefore, sample recoveries following sieving could not be calculated (see Section 3.2.4).

3.2.4 Quality Assurance/Quality Control

Reviews of source sediment chemical data were performed in accordance with PSEP protocols (Tetra Tech 1986c). QA/QC reviews included assessments of accuracy [using standard reference materials (SRMs), matrix spikes, and surrogate recoveries, when applicable] and precision (using analytical replicates). QA/QC reviews also included assessing initial and ongoing calibration and tuning, blank results, sample holding times, and initial performance tests or validation data for certain non-CLP procedures.

Detailed QA/QC reports were prepared for chemical analyses and were compiled in a single document (Tetra Tech 1988a). These reports are not

reproduced in this section, but are summarized below. A complete description of the qualifiers used in this study is provided in Appendix A.

Metals--

The data were considered acceptable as qualified. SRM-1646, certified by the National Bureau of Standards, was analyzed with each batch of 20 samples. Spike recoveries were determined for antimony and selenium, because these elements were not certified in the SRM analyzed. Silver was also not certified in the SRM. However, the analytical laboratory used intercalibration comparisons with other laboratories, and comparison with neutron activation analysis to evaluate accuracy for silver (Crecelius, E., 5 December 1986, personal communication).

The matrix spike recovery data for selenium and antimony were within the control limit criteria (75-125 percent) established by PSEP protocols (Tetra Tech 1986c). Therefore, qualifiers were not assigned to sample results for these compounds. However, all sample results for silver were assigned an "E" qualifier, because matrix spike data or a certified SRM were not available to evaluate accuracy. In some samples, precision data for silver and antimony exceeded the control limit established by PSEP protocols. In these cases, an "E" qualifier was assigned to silver and antimony data, and these results should be considered estimates. Re-analyses of antimony by XRF in several samples from Elliott Bay and Carr Inlet indicated that the antimony data generated by AA in this study were not suitable for use in identifying or ranking problem areas in the receiving environment (see below). However, antimony data were used to rank problem storm drains because three drains exhibited extremely high concentrations (i.e., at least 10 times higher than the other drains).

Detected values for manganese, zinc, and chromium were qualified as estimates based on low recoveries for the SRMs during accuracy analysis. In addition, because the 28-day maximum sample holding time recommended by PSEP was exceeded for all samples, positive sample results for mercury were also considered to be estimates and were assigned an "E" qualifier.

Assessment of the Effect of Analytical Procedures on Metals Results--

The analytical methods used to determine metals in this study were designed to measure the total concentrations of metals in sediments in contrast to methods that rely on partial digestion. A small study was conducted to examine the implications of using PSEP "total metals" methods, especially when comparing results to historical reference area data generated by U.S. EPA CLP "strong acid" methods (e.g., reference area data from Carr Inlet). Selected receiving environment samples collected during the present study from Elliott Bay and Port Susan and two archived Carr Inlet samples collected during the Commencement Bay Remedial Investigation (Tetra Tech 1985a) were re-analyzed using the "total metals" and "strong acid" methods, respectively. The results are presented in PTI and Tetra Tech (1988) and are summarized below.

Differences were observed for a number of metals analyzed by both methods. However, the largest and most consistent differences were observed for chromium. In both Carr Inlet samples, mean chromium concentrations by "total metals" methods (in this case, XRF) were over 4 times the mean concentrations determined by the "strong acid" technique. Samples with higher overall chromium concentrations from Port Susan and Elliott Bay/Duwamish River tended to have a factor of 2 difference between "total metals" and "strong acid" results.

Differences between antimony results by "total metals" vs. "strong acid" methods could not be determined for Carr Inlet samples, because antimony was consistently undetected by the "strong acid" procedure. However, data reported for Samples CR-11 and CR-13 during the Commencement Bay Remedial Investigation were roughly 15 times lower than the "total metals" values. Similarly, for Duwamish River offshore sediment samples WW-12 and EW-15, the "total metals" procedure (including hydrofluoric digestion and analysis by graphite furnace atomic absorption resulted in concentrations roughly 10-20 times higher than concentrations determined by the "strong acid" procedure. This marked discrepancy prompted re-analysis by an independent and more reliable technique for antimony (i.e., XRF). Comparisons between XRF and the "total metals" procedure used in this study suggest that antimony

concentrations observed could be considerable overestimates (e.g., by a factor of 5) (PTI and Tetra Tech 1988).

Because the XRF analysis of antimony aroused sufficient uncertainty about the "total metals" antimony concentrations reported in this study, antimony data were not used to define or rank problem areas in the receiving environment. However, antimony distributions are described in PTI and Tetra Tech (1988), and are used in the evaluation of sources because of their potential value in assessing relative antimony contamination in Elliott Bay. Because XRF results for antimony were sufficiently elevated in some offshore and source sediment samples, antimony may be of concern in Elliott Bay and may warrant further investigation.

Extractable Organic Compounds--

The data were considered acceptable as qualified. Qualifiers were assigned to sample results for reasons that vary in severity. Acid and base/neutral compound data from 17 source samples and pesticide/PCB data from 20 source samples were assigned "E" qualifiers because the extracts were held longer than the PSEP-recommended 40-day maximum holding time (Tetra Tech 1986c). During the initial and continuing GC/MS and GC/ECD calibrations, the relative percent difference (RPD) between response factors for several acid and base/neutral and pesticide compounds exceeded the control limit criteria. Sample data associated with calibrations out of the control limits were therefore assigned an "E" qualifier and were considered estimates. In some cases, precision data exceeded the established control limits. Sample results for compounds that did not meet the required level of precision outlined in PSEP protocols (Tetra Tech 1986c) were assigned an "E" qualifier.

All sample data for endrin aldehyde and total PCBs were considered estimates and were assigned an "E" qualifier due to low recoveries of matrix spikes (recoveries for all six PCB matrix spikes ranged from 0 to 39 percent). Because of excessive laboratory contamination for diethylphthalate, di-n-butylphthalate, and bis(2-ethylhexyl)phthalate, all sample data for these phthalates were rejected and do not appear in the database.

A U.S. EPA policy decision (Gakstatter, J., 10 December 1987, personal communication) required all acid and base/neutral compounds detected below 1,000 ug/kg dry weight to be qualified as estimates. Qualification was recommended based on the laboratory's inability to detect nearly 70 percent of the compounds known to be present in the SRM at levels below 1,000 ug/kg dry weight.

Volatile Organic Compounds--

All detected volatile organic data were considered estimates and assigned an "E" qualifier in the database, because it was not known whether a multipoint calibration was performed by the analytical laboratory. Information provided by the laboratory indicated that a single point calibration was performed at least two times a day, except for analyses of methylene chloride, trichlorofluoromethane, and 1,1,1-trichloroethane data, whose data were rejected due to excessive blank contamination.

Ancillary Analyses--

Quality assurance review was performed for the following conventional variables: total solids, total volatile solids, TOC, total nitrogen, oil and grease, and grain size. Given the nature of the variables evaluated and the methods of analysis, data are considered acceptable as qualified. The absence of recovery data for the grain-size analysis was not considered sufficient justification for qualifying the results. All TOC data were qualified with an "E" and were considered estimates based on SRM results. The mean TOC value determined for the SRM was 2.86 ± 0.07 percent ($n=6$), which was slightly below the certified range (2.99 ± 0.09 percent). No other data were qualified.

4.0 RESULTS OF THE DRAIN SAMPLING INVESTIGATION

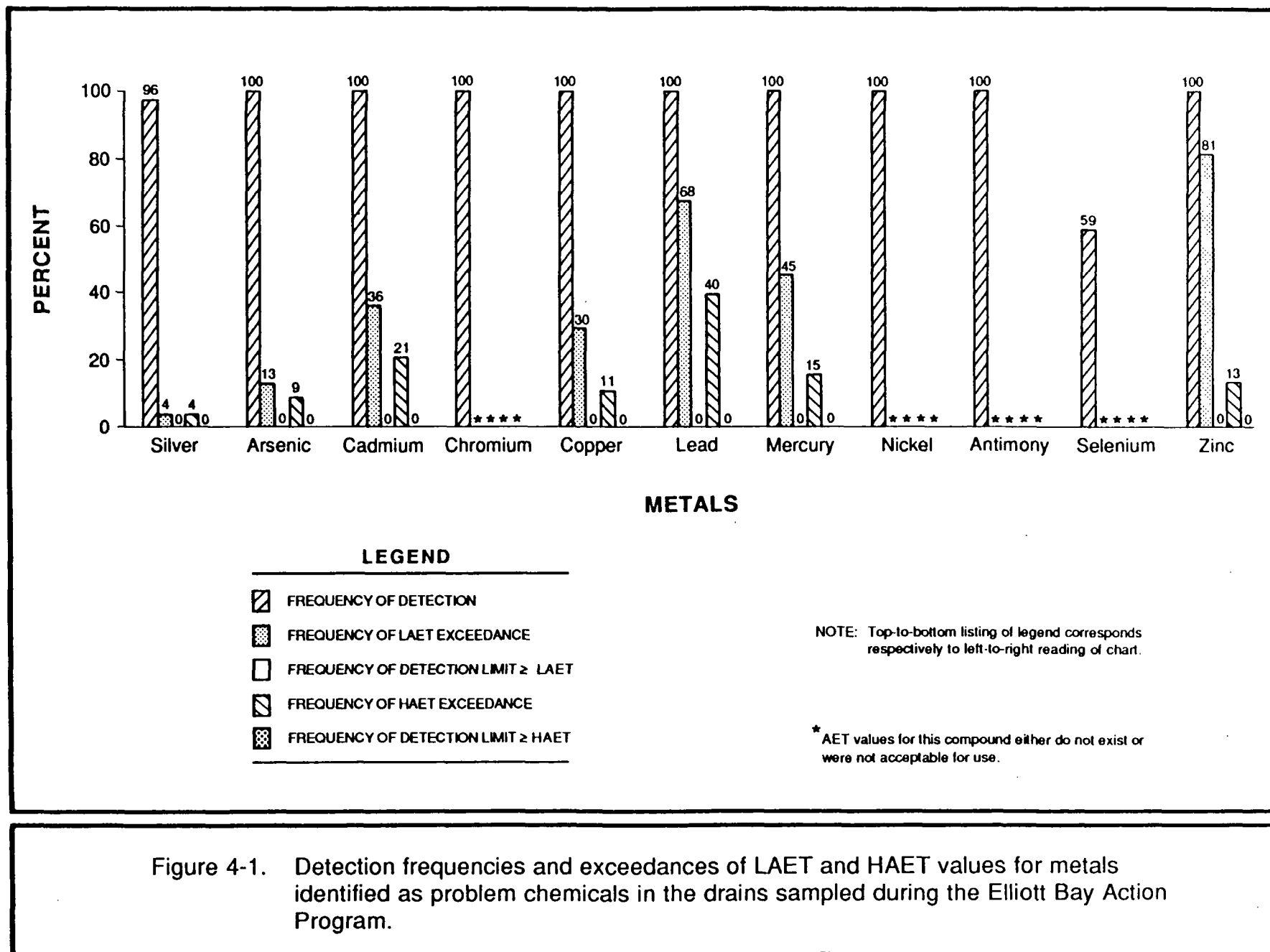
The results of the analyses on the Elliott Bay Action Program drain sediment samples are presented in Appendix A. Analytical concentrations are in mg/kg dry weight for metals and ug/kg dry weight for organic compounds. Unless otherwise noted, all sediment concentrations in this report are reported in dry weight. Data qualifiers are included with the concentration throughout the report. A complete description of data qualifiers is presented in Appendix A.

4.1 PROBLEM CHEMICALS

Detection frequencies and exceedances of LAET and HAET values for the problem chemicals identified in the drains sampled during the Elliott Bay Action Program are summarized in Figures 4-1 to 4-4. Metals were detected in 96-100 percent of the drain sediment samples and were the most frequently detected contaminant. In addition, metals exceeded the HAET value in 4 percent (silver) to 41 percent (lead) of the drains sampled. Lead, identified as a problem chemical in 18 of the 46 source sediment samples, was the most common problem chemical. Metals can be ranked based on the number of drains in which they were identified as problem chemicals as follows: Lead > Cadmium > Mercury > Zinc > Copper, Nickel > Arsenic, Antimony, Chromium > Selenium > Silver.

HAET values were used to identify all problem metals in the drain sediments, except antimony, chromium, nickel, and selenium. The 90th percentile concentration was used to define problem levels of chromium and antimony. Comparisons with AET values were not considered valid for these two metals, because the results of the chemical analyses were affected by the digestion procedures used to prepare the samples (see Section 3.2.4).

Nickel and selenium were identified as problem chemicals based on an exceedance of the 90th percentile concentration because 1) there is no AET



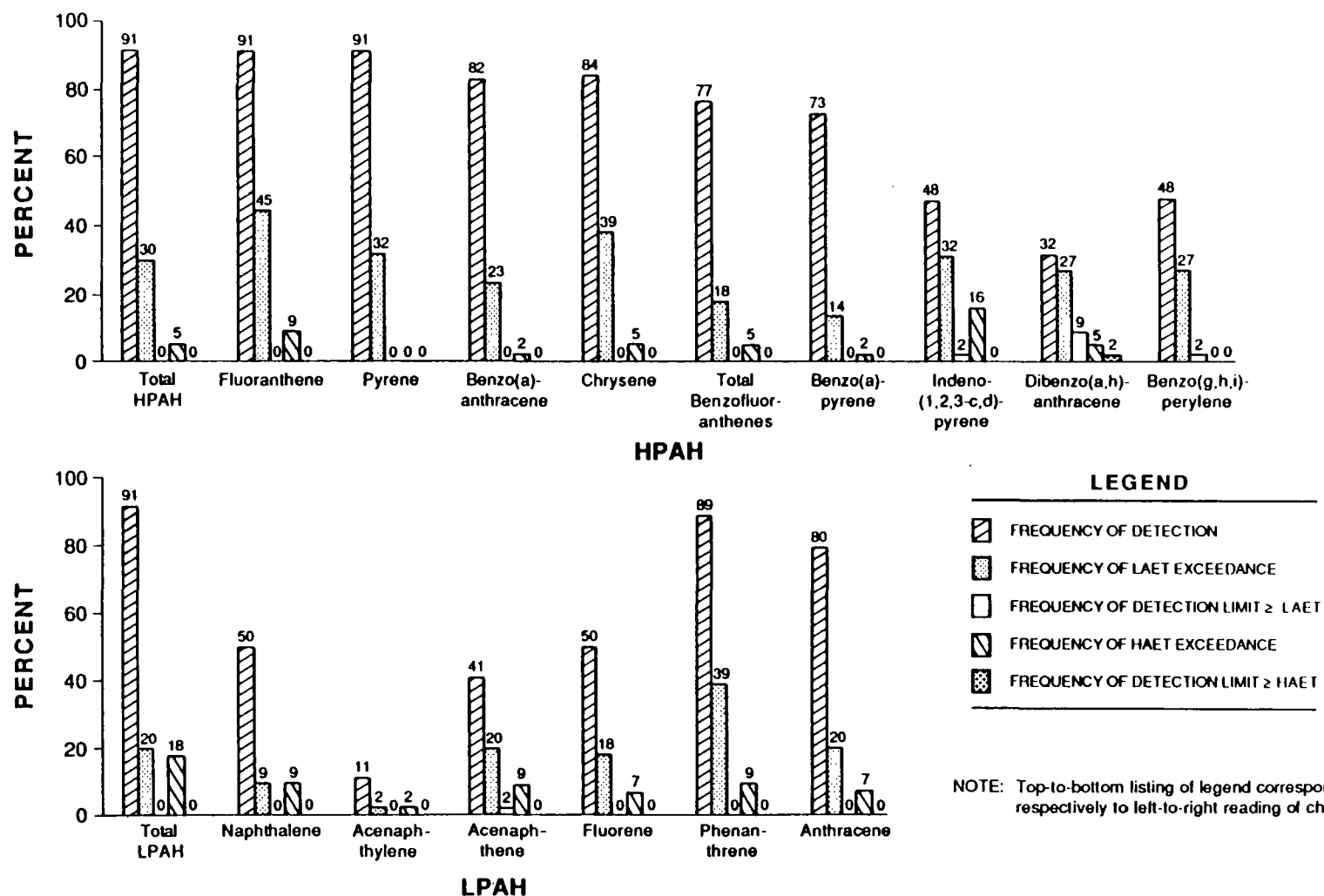


Figure 4-2. Detection frequencies and exceedances of LAET and HAET values for PAH compounds identified as problem chemicals in the drains sampled during the Elliott Bay Action Program.

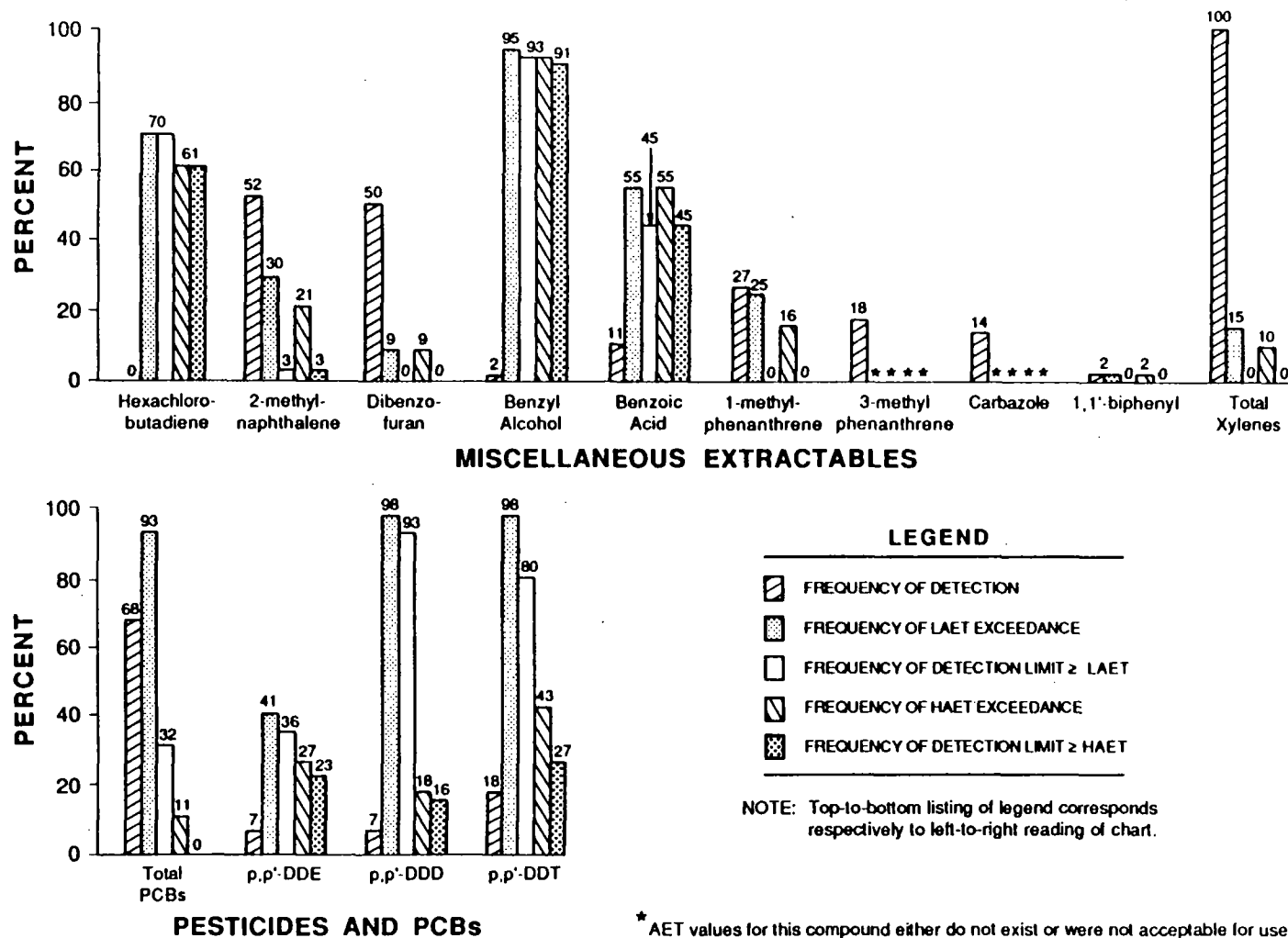
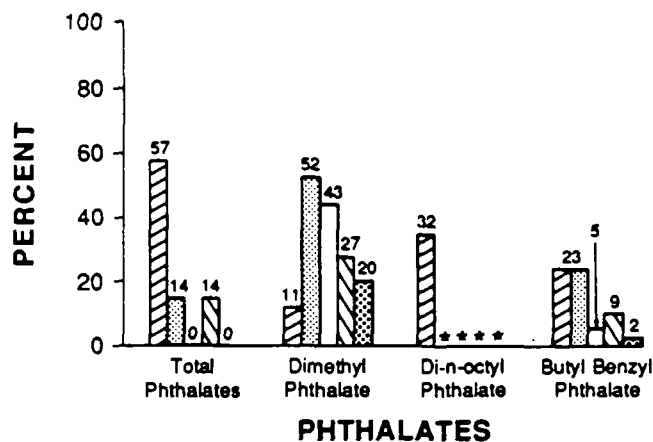
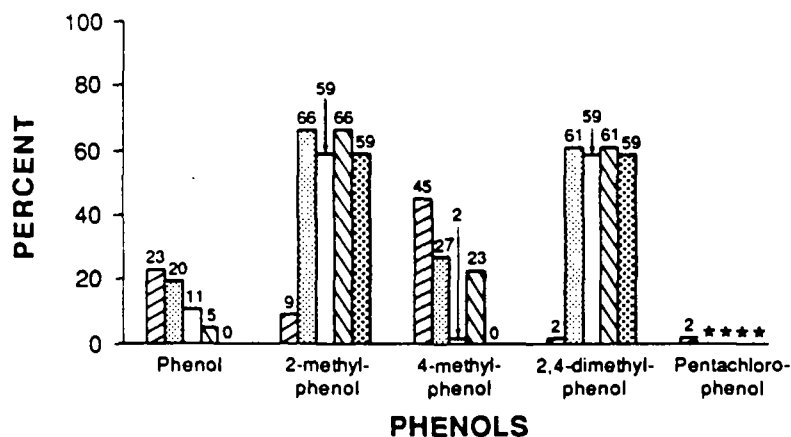
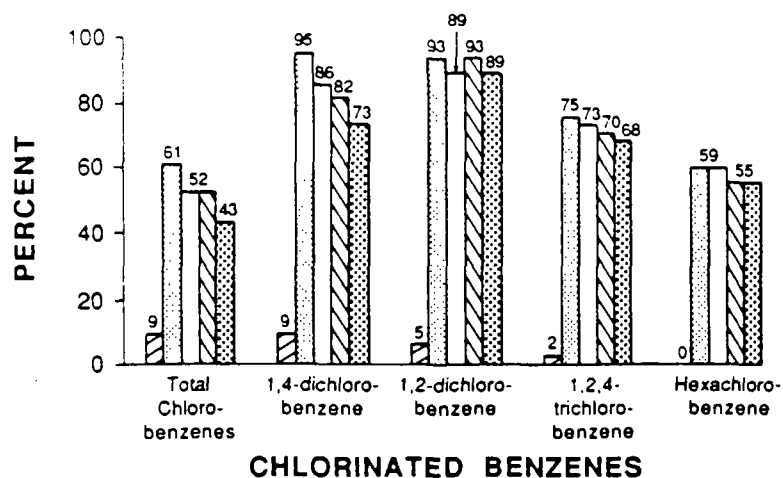


Figure 4-3. Detection frequencies and exceedances of LAET and HAET values for miscellaneous extractable, pesticide, and PCB compounds identified as problem chemicals in the drains sampled during the Elliott Bay Action Program.



LEGEND

- FREQUENCY OF DETECTION
- FREQUENCY OF LAET EXCEEDANCE
- FREQUENCY OF DETECTION LIMIT ≥ LAET
- FREQUENCY OF HAET EXCEEDANCE
- FREQUENCY OF DETECTION LIMIT ≥ HAET

NOTE: Top-to-bottom listing of legend corresponds respectively to left-to-right reading of chart.

* AET values for this compound either do not exist or were not acceptable for use.

Figure 4-4. Detection frequencies and exceedances of LAET and HAET values for chlorinated benzene, phenol, and phthalate compounds identified as problem chemicals in the drains sampled during the Elliott Bay Action Program.

value for selenium, and 2) the database used to generate the AET value for nickel contained a relatively limited range of concentrations (PTI and Tetra Tech 1988). Nickel and selenium were not identified as problem chemicals in the receiving environment sediments (PTI and Tetra Tech 1988) because, in general, they did not exceed the concentrations measured in reference areas [nickel exceeded reference area conditions only at Station SS-10 (Figure 4-5)]. However, nickel and selenium have been identified as problem chemicals for several source stations because their concentrations exceeded the levels measured in all other source stations by 1 order of magnitude.

LPAH (frequency of detection=91 percent), HPAH (91 percent), PCBs (68 percent), phthalates (57 percent), 2-methylnaphthalene (52 percent), dibenzofuran (50 percent), 4-methylphenol (45 percent), and phenol (23 percent) were the most frequently detected organic compounds in the drain sediments. LPAH is defined as the sum of the concentrations of naphthalene, acenaphthylene, fluorene, phenanthrene, acenaphthene, and anthracene. HPAH is defined as the sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene concentrations. The remaining organic compounds were generally detected in less than 20 percent of the source samples analyzed. Chlorinated benzenes, 2,4-dimethylphenol, and pentachlorophenol were among the least frequently detected organic compounds. However, as explained in Section 3.2.4, the analytical laboratory was unable to detect nearly 70 percent of the extractable organic compounds in the SRM at levels below 1,000 ug/kg. Because the HAET values for many extractable organic compounds (i.e., chlorinated benzenes, phenols, and most of the miscellaneous extractable organic compounds) are frequently less than 1,000 ug/kg, it was not possible to accurately evaluate contamination in the drains for these potential problem chemicals.

Extractable organic compounds that were identified as problem chemicals in drain sediments based on exceedances of an HAET or a 90th percentile concentration included phenol, 2-methylphenol, 4-methylphenol, 2,4-dimethylphenol, LPAH, HPAH, PCBs, di-n-octyl phthalate, dimethyl phthalate, butyl benzyl phthalate, total phthalates (sum of di-n-octyl, dimethyl, and butyl benzyl phthalates), 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-tri-

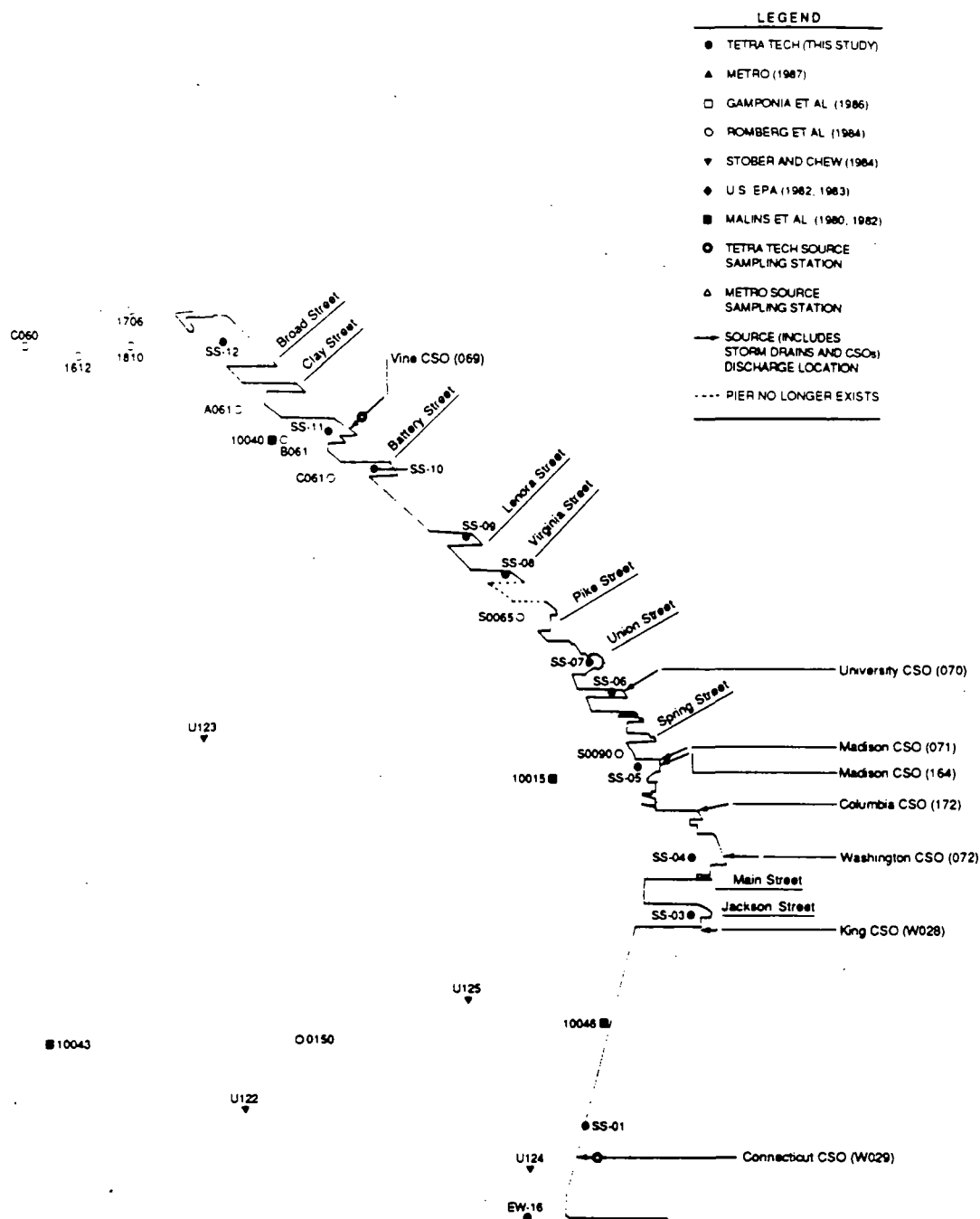


Figure 4-5. Locations of offshore and drain sampling stations, CSOs, and storm drains in the Seattle South Water-front study area.

chlorobenzene, total chlorinated benzenes, 1-methylphenanthrene, 2-methylphenanthrene, 3-methylphenanthrene, 2-methylnaphthalene, biphenyl, dibenzofuran, benzyl alcohol, benzoic acid, and carbazole.

Volatile organic compounds were detected infrequently (0-40 percent) in the drain sediment samples. However, these compounds were not subjected to the same analytical problems as the extractable organic compounds. Detection limits for these compounds were relatively low (i.e. <10 ppb). Therefore, the volatile organics data were used to evaluate contamination in the drains. The most common volatile compounds found in the drains included total xylenes (100 percent), trans-1,2-dichloroethene (40 percent), ethyl benzene (35 percent), tetrachloroethene (20 percent), vinyl chloride (18 percent), and 1,1-dichloroethane (15 percent). All of these volatile organic compounds were identified as problem chemicals in specific drains based on the HAET or 90th percentile criteria.

Pesticides were detected in only 0-18 percent of the source samples. p,p'-DDT, p,p'-DDE, and p,p'-DDD were the most frequently detected pesticides and were identified as problem chemicals based on exceedances of HAET values. Pesticide data also suffered analytical detection limit problems, although not to the same extent as the extractable organic compound results.

The problem chemicals identified in each of the drains sampled during the Elliott Bay Action Program are summarized in Table 4-1. The largest number of problem chemicals was observed in the Fox S. CSO/SD (116)-MH3 (32 problem chemicals), followed by the Michigan CSO (W039) (19 problem chemicals), Slip 4 CSO/SD (117) (16 problem chemicals), the Fox S. CSO/SD (116)-MH1 (13 problem chemicals), the Slip 6 SD (11 problem chemicals), and the Michigan SD (11 problem chemicals). Each of the remaining drains sampled during the study had fewer than 10 problem chemicals.

4.2 CONVENTIONAL SEDIMENT CHARACTERISTICS

The grain size characteristics of the drain sediment samples are summarized in Figures D-1 through D-8 in Appendix D. The drain sediments ranged from sands to clayey silts. However, as was expected, most of the

TABLE 4-1. SUMMARY OF PROBLEM CHEMICALS IN DRAINS

Drain	Number of Problem Chemicals	Chemicals Exceeding HAET Value or the 90th Percentile Concentration
North Seattle Waterfront		
Pier 91 SD	3	Butyl benzyl phthalate ^b , p,p'-DDD, total phthalates
Interbay CSO/SD (068)	6	4-Methylphenol, naphthalene, acenaphthene, dibenzofuran, 2-methylnaphthalene, LPAH
Denny Way CSO (W027)	3	Ag, Hg, 1-methylphenanthrene
South Seattle Waterfront		
Vine St. CSO (069)	5	Pb, Hg, benzyl alcohol ^b , LPAH, 2-methylphenol
Connecticut CSO (W029)	0	
North Harbor Island		
11th Ave. SW CSO/SD (077)	4	Cd, Pb, fluoranthene, indeno(1,2,3-c,d)pyrene
Longfellow Creek	5	Cu, Ni ^a , 4-methylphenol, p,p'-DDT, PCBs
East Waterway		
SW Florida SD (36 in)	1	p,p'-DDT
SW Lander SD (15 in)	1	Dimethyl phthalate
SW Hanford CSO/SD (162)	9	Cu ^b , Pb, Zn, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, 1-methylphenanthrene, chlorobenzenes, PCBs ^b , Se ^a
SW Spokane CSO/SD (163) ^c	3	Cd, Pb, Se ^a
S. Hinds CSO/SD (107)	1	Pb
Hanford CSO (W032)	5	Cr ^a , Hg, 4-methylphenol, 2-methylnaphthalene, butyl benzyl phthalate
Lander CSO (W030)	1	Cd
West Waterway		
SW Florida CSO/SD (098)	0	
SW Hinds CSO/SD (099)	1	4-Methylphenol
SW Spokane CSO/SD (102)	3	Cr ^{a,b} , Ni ^a , benzoic acid
16th Ave SW CSO/SD (104)	4	Pb, 2-methylphenol ^b , 1-methylphenanthrene, p,p'-DDT
SW Lander CSO/SD (105)	3	Sb ^a , Pb ^b , total xylenes ^b
SW Lander SD (21 in)	0	

TABLE 4-1 (Continued).

Drain	Number of Problem Chemicals	Chemicals Exceeding HAET Value or the 90th Percentile Concentration
SW Florida CSO/SD (106)	2	Pb, benzoic acid
Kellogg Island		
SW Dakota SD	0	
SW Idaho	0	
Diagonal Ave. S. SD	2	Indeno(1,2,3-c,d)pyrene, total phthalates
Diagonal Way CSO/SD (111)-MH	7	1,4-Dichlorobenzene ^b , indeno(1,2,3-c,d)pyrene, 1,2-dichlorobenzene, chlorobenzenes ^b , phenol ^b , 4-methylphenol, dimethyl phthalate
Diagonal Way CSO/SD (111)-Pipe	2	1,4-Dichlorobenzene, chlorobenzenes
S. Nevada SD	3	Cd, Cr ^a , Pb
Duwamish River		
Duwamish SD	7	As ^b , Cd, Cu, Pb, Zn ^b , Hg ^b , Sb ^{a,b}
SW Graham SD	0	
Michigan SD	11	Naphthalene ^b , acenaphthylene ^b , acenaphthene, fluorene, total phthalates, 2,4-dimethylphenol, phenanthrene, anthracene, LPAH, dibenzofuran ^b , 2-methylphenol
2nd Ave S. SD	0	
S. 96th SD	0	
Slip 6 SD	10	Phenanthrene, fluoranthene, pyrene, chrysene, carbazole ^d , benzo(b)fluoranthene, benzo(k)fluoranthene, LPAH, indeno(1,2,3-c,d)pyrene ^a , HPAH
Isaacson CSO/SD (156)	2	Cd, Cr ^a
16th Ave S. SD	5	Pb, Dimethyl phthalate ^b , PCBs, total phthalates, benzoic acid
Slip 4 SD	0	
Slip 4 CSO/SD (117)	16	Cd ^b , Pb, Ag ^b , Hg, 4-methylphenol, naphthalene, indeno(1,2,3-c,d)pyrene, fluorene, phenanthrene, fluoranthene, 2-methylnaphthalene ^b , LPAH, p,p'-DDE ^b , p,p'-DDT ^b , PCBs, HPAH
I-5 SD MH1	0	
I-5 SD MH2	1	Pb

TABLE 4-1 (Continued).

Drain	Number of Problem Chemicals	Chemicals Exceeding HAET Value or the 90th Percentile Concentration
Fox S. CSO/SD (116)-MH1	13	As, Cd, Cu, Pb, Zn, 4-methylphenol, anthracene, total phthalates ^b , 3-methylphenanthrene ^d , benzoic acid ^b , di-n-octyl phthalate ^b , LPAH, 1-methylphenanthrene
Fox S. CSO/SD (116)-MH2	4	As, Pb, Zn, Sb ^a
Fox S. CSO/SD (116)-MH3	32	As, Cu, Pb, Zn, Sb ^a , 4-methylphenol, naphthalene, acenaphthene ^b , fluorene ^b , phenanthrene ^b , anthracene ^b , fluoranthene ^b , pyrene ^b , benzo(a)anthracene ^b , chrysene ^b , benzo(b)fluoranthene ^b , benzo(k)fluoranthene ^b , benzo(a)pyrene ^b , dibenzo(a,h)-anthracene ^b , dibenzofuran, 2-methylnaphthalene, 1,1-biphenyl, 1-methylphenanthrene, benzofluoranthene ^b , indeno(1,2,3-c,d)pyrene ^{a,b} , HPAH ^b , LPAH ^b , 3-methylphenanthrene ^d , 2-methylphenanthrene ^d , 1,1-dichloroethane ^d , vinyl chloride ^d , trans-1,2-dichloroethene ^d
S. River SD ^c	1	Pb
Michigan CSO (W039)	19	Cd, Pb, Ni ^a , Hg, 4-methylphenol, acenaphthene, indeno(1,2,3-c,d)pyrene, total phthalates, 2-methylnaphthalene, 1-methylphenanthrene, LPAH, chlorobenzenes, 1,4-dichlorobenzene, 1,2-dichlorobenzene ^b , p,p'-DDE, p,p'-DDT, PCBs, total xylenes, butyl benzyl phthalate
Brandon CSO (W041)	8	Cd, Pb, Se ^{a,b} , Ni ^{a,b} , Zn, Hg, 4-methylphenol ^b , 2-methylnaphthalene
Alki Beach		
56th Ave. SW SD	1	p,p'-DDT

^a Chemical exceeds 90th percentile concentration.

^b Highest observed concentration occurred in sediment samples from this drain.

^c No data for organic compounds.

^d Did not exceed AET but was the highest concentration observed in source study.

sediments were relatively coarse-grained (i.e., sands). Due to the hydraulic characteristics of the drains, sediment samples are typically biased toward coarser-grained materials because the fine-grained materials are flushed out of the drain system rather than being deposited. In general, the sediments from the drains were more coarse-grained than the corresponding offshore receiving environment sediments.

Total organic carbon content of the drain sediments (see Table A-20 in Appendix A) ranged from 0.5 (I-5 SD) to 26.5 percent (Slip 4 CS0/SD). Most of the sediments contained less than 5 percent TOC. In general, the range of TOC content in the drain sediments was similar to the range measured in the offshore receiving environment, although some differences occurred between individual drains and the corresponding offshore sediment station.

Because contaminants are frequently associated with the fine-grained materials (i.e., silts and clays) and organic matter, differences in grain size and TOC content of the drain sediments and offshore sediment samples must be taken into account when comparing data from different stations. To eliminate the effects of these differences, inter-drain, and drain to receiving environment comparisons were conducted using the relative distribution of contaminants in the samples rather than the concentration. This approach was used to compare the relative distributions of metals, LPAH, and HPAH (see Sections 4.3, 5.1, and 5.2). Direct comparisons of contaminant concentrations between stations were generally not made. For contaminants other than metals, LPAH, and HPAH, the comparison evaluations have been made based on the occurrence of the same problem chemicals among drains and offshore sediment stations.

4.3 INTER-DRAIN COMPARISONS

The analytical results of the initial screening of CSOs and storm drains in the Elliott Bay project area are described in the following sections. The discussion is organized by study areas to facilitate comparisons between drains. Sediment contaminant concentrations, as well as their relative distributions, are compared to identify possible similarities within the various drains sampled and the ultimate one or more sources.

Storm drain sediments are expected to exhibit background levels of contamination due to contributions from normal urban runoff. Therefore, the following analyses used available street dust data (Galvin and Moore 1982) to characterize background contaminant levels and to identify drains where sediment contamination appeared to be related to sources other than normal urban runoff (Tables 4-2 and 4-3). In addition, CSO/SD data from Metro's Industrial Non-Point Source Investigations (Sample, T., 23 October 1987, personal conversation) have been included in the discussion to help identify problem drains and potential sources of contamination.

4.3.1 Magnolia

No CSOs or storm drains in the Magnolia study area were sampled during this investigation. An attempt was made to sample the 32nd Ave. W. SD, but because of the steep gradients on the drain lines, there were insufficient sediment deposits in the manholes. The CSOs that discharge into Elliott Bay in the Magnolia segment (Figure 4-6) either function only as emergency overflows or have been controlled so that they overflow once a year or less (Corson, C., 6 May 1988, personal communication). Storm drains in the Magnolia segment serve primarily residential areas and are not expected to be major sources of contaminants to the offshore sediments.

4.3.2 Seattle North Waterfront

During the Elliott Bay Action Program, sediment samples were collected from the three largest drains discharging into the Seattle North Waterfront area [i.e., Pier 91 SD, Interbay CSO/SD (068), and Denny Way CSO (W027); Figure 4-7].

Metals--

Results of the metals analyses are summarized in Figure 4-8. Only the Denny Way CSO exhibited exceedances of HAET for metals (silver and mercury). Silver concentrations in the Denny Way CSO sediments were the second highest observed during the source sampling program. The Denny Way CSO sediment data are also consistent with the results of Metro's effluent monitoring of Denny

TABLE 4-2. SUMMARY OF METALS MEASURED IN STREET DUST SAMPLES
COLLECTED FROM SEATTLE AND BELLEVUE^a

Chemical	Range (mg/kg wet wt)	Mean ^b (mg/kg wet wt)	Detection Frequency
Antimony	<1-2.0	1.1	8/12
Arsenic	11-39	25	12/12
Beryllium	0.17-0.34	0.26	12/12
Cadmium	0.6-2.0	1.0	12/12
Chromium	20-230	97	12/12
Copper	31-260	93	12/12
Lead	90-1,300	520	12/12
Mercury	0.02-0.18	0.07	9/12
Nickel	20-44	32	12/12
Selenium	<0.6-<3	2	0/12
Silver	0.01-0.5	0.32	6/12
Thallium	<0.2-<1	0.6	3/12
Zinc	110-970	310	12/12

^a Street dust sampled collected from five residential areas and three suburban arterials in Bellevue, and from two industrial and two commercial areas in Seattle. Concentrations were reported as wet weight, but the street dust was collected with a "dry vacuum cleaner" and had a very low moisture content, estimated to be 10 percent or less (Galvin, D., 15 July 1988, personal communication).

^b Mean calculated using the reported detection limit for undetected values.

Reference: Galvin and Moore (1982).

TABLE 4-3. SUMMARY OF ORGANIC COMPOUNDS
MEASURED IN STREET DUST SAMPLES COLLECTED FROM
SEATTLE AND BELLEVUE^a

Chemical	Mean ^b (mg/kg wet wt)	Range ^b (mg/kg wet wt)	Detection Frequency
<u>Pesticides</u>			
alpha-Hexachlorocyclohexane	0.014	0.010-0.018	2/14
gamma-Hexachlorocyclohexane	0.025	0.006-0.043	2/14
p,p'-DDD	0.005	0.005	1/14
Heptachlor	0.048	0.048	1/14
<u>Halogenated aliphatics</u>			
Trichloromethane	0.007	0.004-0.015	4/14
Tetrachloroethane	0.024	0.016-0.032	2/14
1,1,1-Trichloroethane	0.013	0.012-0.016	3/14
4-Chlorophenyl phenyl ether	0.24	0.24	1/14
<u>Monocyclic aromatic hydrocarbons</u>			
Benzene	0.021	0.01-0.032	2/14
Hexachlorobenzene	2.0	2.0	1/14
Ethyl benzene	0.021	0.005-0.025	3/14
Toluene	0.009	0.004-0.019	4/14
Nitrosodimethylamine	0.76	0.76	1/14
<u>Phenols</u>			
Phenol	0.21	0.08-0.47	4/14
Pentachlorophenol	1.76	0.12-3.4	2/14
2,4-Dimethylphenol	0.02	0.01-0.03	2/14
4-Nitrophenol	0.11	0.11	1/14
<u>Phthalates</u>			
Dimethyl phthalate	0.78	0.78	1/14
Diethyl phthalate	0.41	0.16-0.89	3/14
Di-n-butyl phthalate	0.70	0.22-2.4	7/14
Di-n-octyl phthalate	0.54	0.23-0.97	4/14
Butyl benzyl phthalate	6.2	0.22-0.35	7/14
Bis-2-ethylhexyl phthalate	38	2.4-90	9/14

TABLE 4-3. (Continued)

Chemical	Mean ^b (mg/kg wet wt)	Range ^b (mg/kg wet wt)	Detection Frequency
<u>LPAH</u>			
Acenaphthylene	0.21	0.16-0.25	2/14
Anthracene	0.35	0.1-0.6	5/14
Fluorene	0.23	0.2-0.25	2/14
Phenanthrene	1.5	0.18-2.4	14/14
<u>HPAH</u>			
Fluoranthene	1.7	0.36-2.6	14/14
Pyrene	1.7	0.32-2.5	13/14
Chrysene	1.04	0.11-2.0	11/14
Benzo(a)pyrene	0.63	0.08-0.90	7/14
Benzo(k)fluoranthene	1.1	0.27-1.5	8/14
Benzo(a)anthracene	0.63	0.20-0.85	7/14

^a Street dust samples were collected from five residential areas and three suburban arterials in Bellevue, and from two industrial and two commercial areas in Seattle. Concentrations were reported as wet weight, but the street dust was collected with a "dry vacuum cleaner" and had a very low moisture content, estimated to be 10 percent or less (Galvin, D., 15 July 1988, personal communication).

^b Calculation based on detected values only.

Reference: Galvin and Moore (1982).

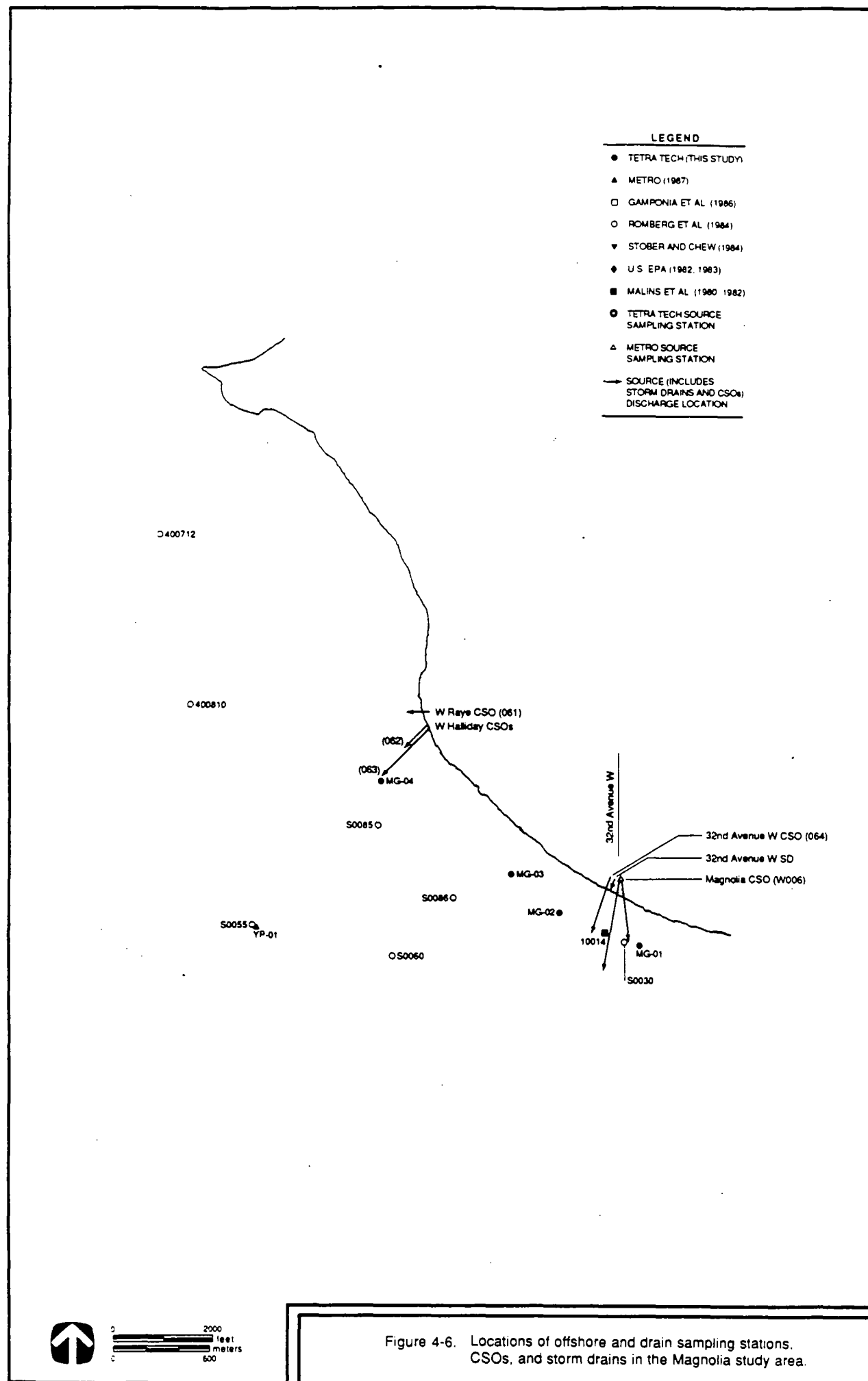
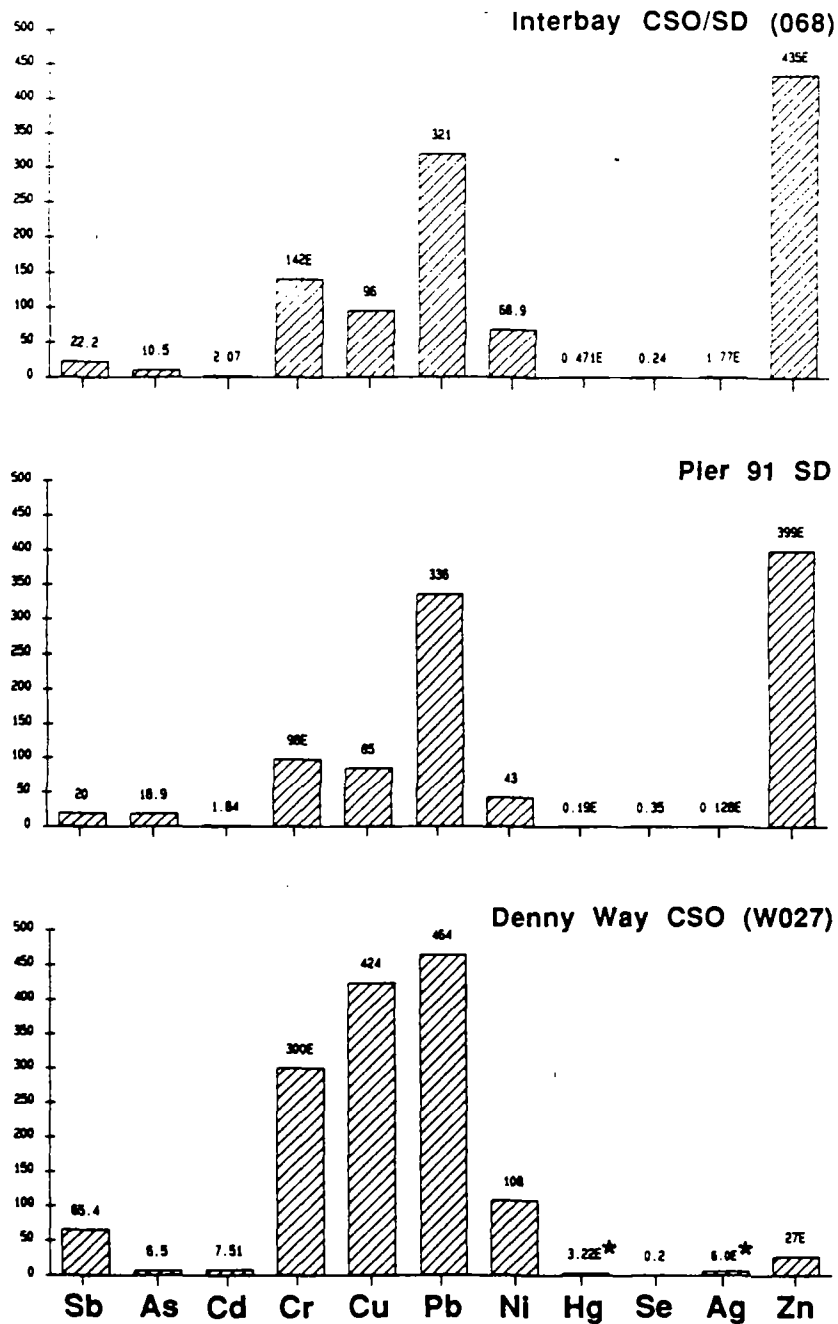


Figure 4-6. Locations of offshore and drain sampling stations, CSOs, and storm drains in the Magnolia study area.

CONCENTRATION (mg/kg dry weight)



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-8. Concentrations of metals in sediments collected from drains discharging into the North Seattle Waterfront study area.

Way discharges, which showed elevated concentrations of silver (relative to other Metro CSOs) in Denny Way overflows (Metro 1984). Silver concentrations in the Denny Way system were 3-11 times greater than the silver concentrations measured in the Michigan (W039), Lander (W030), Hanford (W032), King (W028), and Harbor (W037) CSOs.

The relatively high silver concentrations may be related to the large number of printing (138) and photographic and graphic (94) facilities operating in the Denny Way basin (Romberg et al. 1987). Silver is a major component of compounds commonly used in photographic emulsions (Kirk-Othmer 1985; see Appendix H). These silver containing compounds are primarily associated with the fixation step in the film developing process. Metro's Industrial Waste Section has encouraged the photographic facilities to conduct onsite waste reclamation or to send their fixer solutions offsite for reclamation (Romberg et al. 1987). Consequently, Metro has reported that the input of silver to the Denny Way CSO system has been substantially reduced (Romberg et al. 1987).

The relative distribution of metals in the sediments from the Pier 91 SD and Interbay CSO/SD (068) was similar (Table 4-4), with zinc the most abundant metal (40 percent), followed by lead (29-34 percent), chromium (10-13 percent), and copper (8-9 percent). The relative distribution of metals in these two drains was similar to the relative distribution of metals in urban street dust (Table 4-4), which suggests that the metals may have been contributed from nonpoint sources such as urban runoff. However, in the Denny Way CSO, zinc was a relatively minor (2 percent) constituent. Lead (33 percent), copper (30 percent), and chromium (21 percent) were the primary metals observed in sediments from the Denny Way CSO. These differences suggest that the potential contaminant sources in the Denny Way basin may have been different from the sources in either the Pier 91 SD or Interbay CSO/SD (068) basins.

Metro identified a motion picture film developing operation as a source of chromium to the Denny Way system (Romberg et al. 1987). This source has been directed to use proper disposal practices, and Metro expects the input of chromium from this source to decline substantially. Other potential

TABLE 4-4. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS
FROM DRAINS DISCHARGING INTO THE NORTH SEATTLE WATERFRONT STUDY AREA

Metals	Pier 91 SD	Interbay CSO/SD (068)	Denny Way CSO (W027)	Street Dust ^a
Antimony	2	2	25	<1
Arsenic	2	1	<1	1-5
Cadmium	<1	<1	<1	<1
Chromium	10	13	21	2-15
Copper	8	9	30	4-12
Lead	34	29	33	30-64
Mercury	<1	<1	<1	<1
Nickel	4	6	8	2-4
Silver	<1	<1	<1	<1
Zinc	40	40	2	14-54
Total metals (mg/kg)	1,000 ^b	1,100 ^b	1,400 ^b	680-1,800 ^c

^a Commercial and industrial sites (Galvin and Moore 1982).

^b Values reported as dry-weight concentrations.

^c Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

sources of metals in the Denny Way system are two industrial laundries and an electroplating operation, which have industrial pretreatment permits from Metro to discharge wastes to the sanitary sewer system. However, the combined discharge from these facilities (203,000 gal/day) accounts for less than 2 percent of the total base flow in the Denny system (Romberg et al. 1987).

Organic Compounds--

Selected organic compounds measured in sediments collected from the drains discharging into the Seattle North study area are summarized in Figure 4-9. PAHs were the organic compounds that were measured in the highest concentrations in the three drains sampled; however, PAHs were identified as problem chemicals only in the Interbay CSO/SD (068) and the Denny Way CSO (W027). The following organic compounds were identified as problem chemicals in the Seattle North study area drains:

- Pier 91 SD - butyl benzyl phthalate, total phthalates, and p,p'-DDT
- Denny Way CSO (W027) - 1-methylphenanthrene
- Interbay CSO/SD (068) - naphthalene, acenaphthene, LPAH, 2-methylnaphthalene, dibenzofuran, and 4-methylphenol.

The relative proportion of HPAH to LPAH varied in each drain. HPAH and LPAH concentrations were approximately equal in the sediments from the Interbay CSO/SD (068). In the Pier 91 SD, the HPAH concentration was roughly double the LPAH concentration. The HPAH concentration was approximately 4 times the LPAH concentration in the Denny Way CSO (W027). The ratio of HPAH to LPAH in sediments can be used to indicate potential sources. HPAH compounds are characteristic of combusted fuel material, while LPAH compounds are characteristic of unburned fossil fuels (Lee et al. 1977). Consequently, the sources of PAH may vary in the three basins.

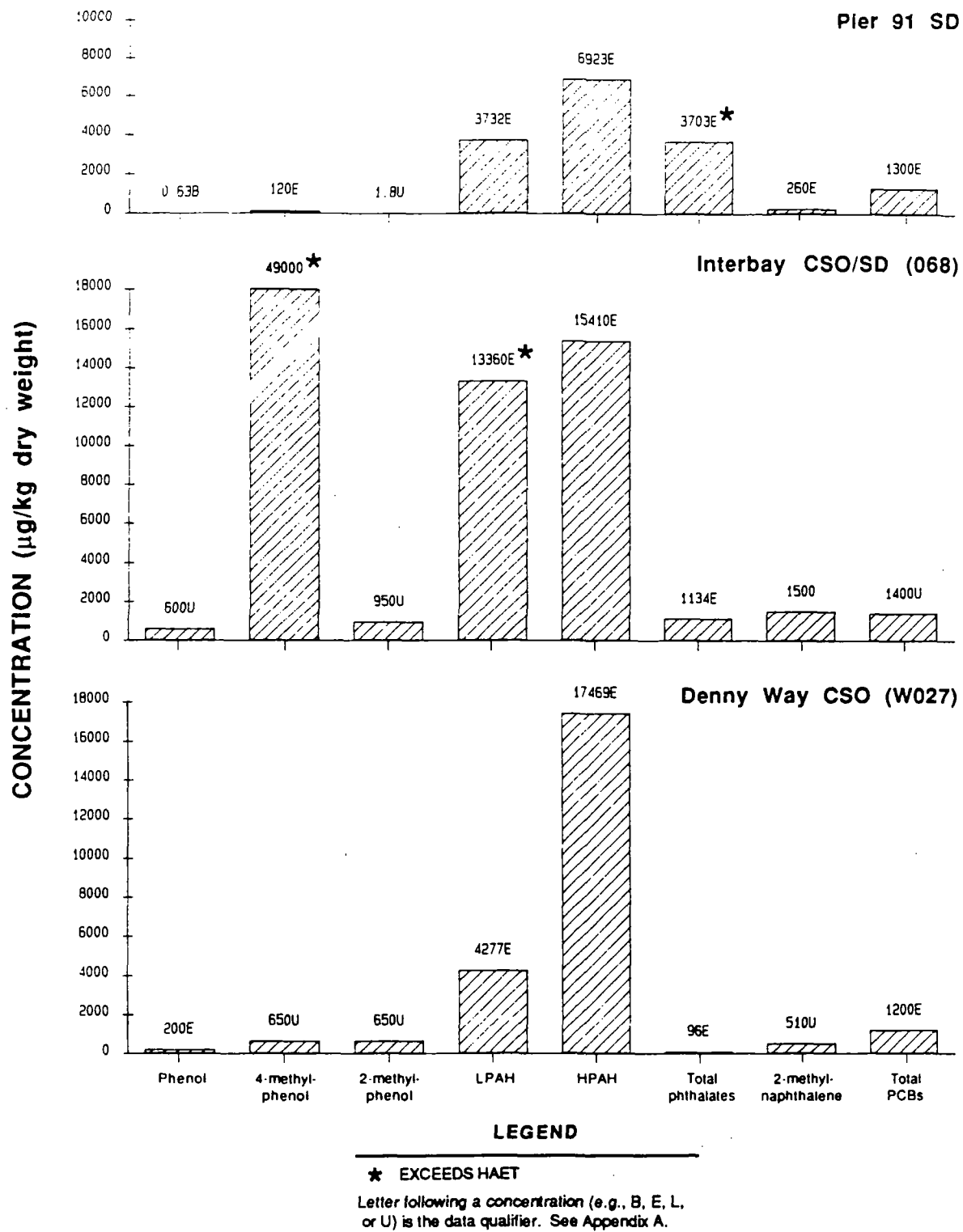


Figure 4-9. Concentrations of selected organic compounds in sediments collected from drains discharging into the Seattle North Waterfront study area.

4-Methylphenol was identified as a problem chemical in the Interbay CSO/SD (068) at a concentration (49,000 ug/kg) that was 75 and 400 times greater than the concentrations measured in the Denny Way CSO (W027) and Pier 91 SD, respectively. 4-Methylphenol has a wide variety of uses (see Appendix H) including as a plasticizer in fire retardants, phenolic resins, and magnet wire; and an antioxidant (i.e., butylated hydroxytoluene) (Burch, W., 1 September 1987, personal communication). Specific sources in the primarily industrial and commercial basin of the Interbay CSO/SD (068) are unknown.

Volatile organic compounds were analyzed only in the sediment sample collected from the Interbay CSO/SD (068). Total xylenes and trans-1,2-dichloroethene were the only volatile organic compounds detected in the sediments from the Interbay CSO/SD (068). However, the concentrations were less than the 90th percentile concentration, E3.8 ug/kg and E0.2 ug/kg, respectively. Therefore, these compounds were not classified as problem chemicals.

Total phthalates and butyl benzyl phthalate were identified as problem chemicals in the Pier 91 SD. The concentration of butyl benzyl phthalate measured in Pier 91 SD sediment (E3,700 ug/kg) was the highest observed in the source sampling program. The concentration of total phthalates (dimethyl, butyl benzyl, and di-n-octyl phthalate) in sediment from the Pier 91 SD was 3.3-39 times greater than the concentrations measured in the Interbay CSO/SD (068) and Denny Way CSO (W027), respectively (see Figure 4-9).

Phthalates are used as plasticizers in a wide variety of products (see Appendix H). Therefore, there could be many potential sources of phthalates in the Pier 91 basin. The Pier 91 SD receives discharges from a series of settling ponds located at 20th Ave. W. and W. Halliday St. Sediments removed from catch basins by the City of Seattle, as part of their storm drain maintenance program, are deposited in these settling ponds prior to discharge to Elliott Bay (Cargill, D., 25 February 1988, personal communication). Because the ponds receive sediment from catch basins throughout the

Seattle metropolitan area, they are a potential source of many contaminants, including phthalates to the Pier 91 SD.

4.3.3 Seattle South Waterfront

Sediment samples were collected from two [Vine CSO (069) and Connecticut CSO (W029)] of the eight CSOs that discharge into the Seattle South Waterfront (see Figure 4-5). Samples could not be collected from the University (070), Madison (071/164), or King (W028) CSOs, because there were insufficient sediment deposits in the discharge lines and at the overflow structure. No attempt was made to collect sediment samples from the Washington CSO (072) and the Columbia CSO (172) because of the relatively small volume discharged from these two CSOs, 17 Mgal/yr and 0 Mgal/yr, respectively.

Metals--

Results of the metals analyses for the Vine (069) and Connecticut (W029) CSOs are discussed in Section 4.4.1 (see Figure 4-36). No metals exceeded HAET in the Connecticut CSO (W029) sediments. Sediments from the Vine CSO (069) exceeded HAET for lead and mercury. No known sources of lead and mercury exist in the Vine CSO basin. Four facilities in the basin have Metro industrial pretreatment permits; however, only one facility, a metal plating company, is considered a major discharger (Hildebrand, D., 16 October 1987, personal communication). Lead concentrations in the effluent from this facility, monitored periodically by Metro, ranged from 0.02 mg/L to 0.04 mg/L between May 1985 and April 1986 (Hildebrand, D., 16 October 1987, personal communication). Metro does not analyze for mercury in the metal plater's effluent.

Chromium, copper, lead, and zinc were the primary metals in both CSOs. However, the relative distribution of metals (shown as a percentage) differed between the two locations:

<u>Chemical</u>	<u>Connecticut CSO (W029)</u>	<u>Vine CSO (069)</u>	<u>Industrial/Commercial Street Dust (Galvin and Moore 1982)</u>
Chromium	8	16	2-15
Copper	19	8	4-12
Lead	31	51	30-64
Zinc	30	17	14-54
Total metals (mg/kg)	1,100	1,700	700-1,800

The relative abundances of chromium and copper were reversed in the two samples. In addition, the Vine CSO (069) contained a higher percentage of lead (51 percent) than the Connecticut CSO (W029) (31 percent). However, the relative distribution of metals in both samples was within the ranges observed for urban street dust. Therefore, the observed contamination may have been caused by urban runoff.

Organic Compounds--

Selected organic compounds measured in the sediments from the Vine CSO (069) and Connecticut CSO (W029) are discussed in Section 4.4.1 (see Figure 4-37). Sediments from the Vine CSO (069) exceeded the HAET for 2-methylphenol, LPAH, and benzyl alcohol. There were no exceedances of HAET or the 90th percentile concentration in the sediments collected from the Connecticut CSO (W029). With the exception of PAH and phenol, most organic compounds were undetected in the Connecticut CSO (W029) sediments.

LPAH is commonly found in urban street dust (Galvin and Moore 1982). Anthracene and phenanthrene are generally the LPAH components that are detected most frequently. Galvin and Moore (1982) reported that phenanthrene was detected in 100 percent of the street dust samples, at concentrations of 180-2,400 ug/kg; and anthracene was detected in 36 percent of the samples, at concentrations of 100-600 ug/kg. Phenanthrene and anthracene comprised the largest percentage of the Vine CSO (069) sediments, at 65 percent and 17 percent, respectively (see Table 4-21 in Section 4.1.1). Therefore, LPAH contamination in Vine CSO (069) sediments may have been caused by urban runoff.

The Vine CSO (069) was the only drain sampled that exceeded the HAET for benzyl alcohol. However, the analytical detection limit for benzyl alcohol exceeded the HAET in 91 percent of the samples. Benzyl alcohol has a variety of industrial uses (see Appendix H), many of which are related to the dye and pigment industry: in perfumes, and flavors; in photographic developer for color movie films; in nylon filament dyeing, textiles, and sheet plastics; as a solvent for dyestuffs, cellulose esters, casein, and waxes; in heat-sealing polyethylene films; as a chemical intermediate for benzyl esters, and benzyl bromide; as a bacteriostat; in cosmetics, ointments, and emulsions; in ballpoint pen inks; and stencil inks (Hawley 1981). There are no documented sources of benzyl alcohol in the basin. One paper printing facility, located on the Vine CSO (069) service area boundary, has been included on U.S. EPA's CERCLIS (U.S. EPA, 22 October 1987, personal communication).

Specific sources of 2-methylphenol in the Vine CSO (069) basin have not been documented. The Vine CSO (069) serves a primarily commercial area in downtown Seattle (see Map 1 in Map Appendix). 2-Methylphenol is frequently found in pulp mill effluents (Tetra Tech 1986a) and has been found in sediments offshore of pulp mills (Tetra Tech 1985a). No industries related to wood products have been identified in the basin. Uses of 2-methylphenol are presented in Appendix H.

4.3.4 North Harbor Island

In the North Harbor Island study area, sediment samples were collected from the 11th Ave. SW CSO/SD (077) and from lower Longfellow Creek (Figure 4-10). These are the only two city drains in the area. However, there are numerous private drains that discharge off the north end of Harbor Island and the West Seattle portion of the study area (Figures 4-10 and 4-11).

Metals--

The results of the metals analyses from these drain sediments are summarized in Figure 4-12. Each of the drains exhibited different problem

- LEGEND**
- TETRA TECH (THIS STUDY)
 - ▲ METRO (1987)
 - GAMPONIA ET AL (1986)
 - ROMBERG ET AL (1984)
 - ▼ STOVER AND CHEW (1984)
 - ◆ U.S. EPA (1982, 1983)
 - MALINS ET AL. (1980, 1982)
 - TETRA TECH SOURCE SAMPLING STATION
 - ▲ METRO SOURCE SAMPLING STATION
 - SOURCE (INCLUDES STORM DRAINS AND CSOs) DISCHARGE LOCATION

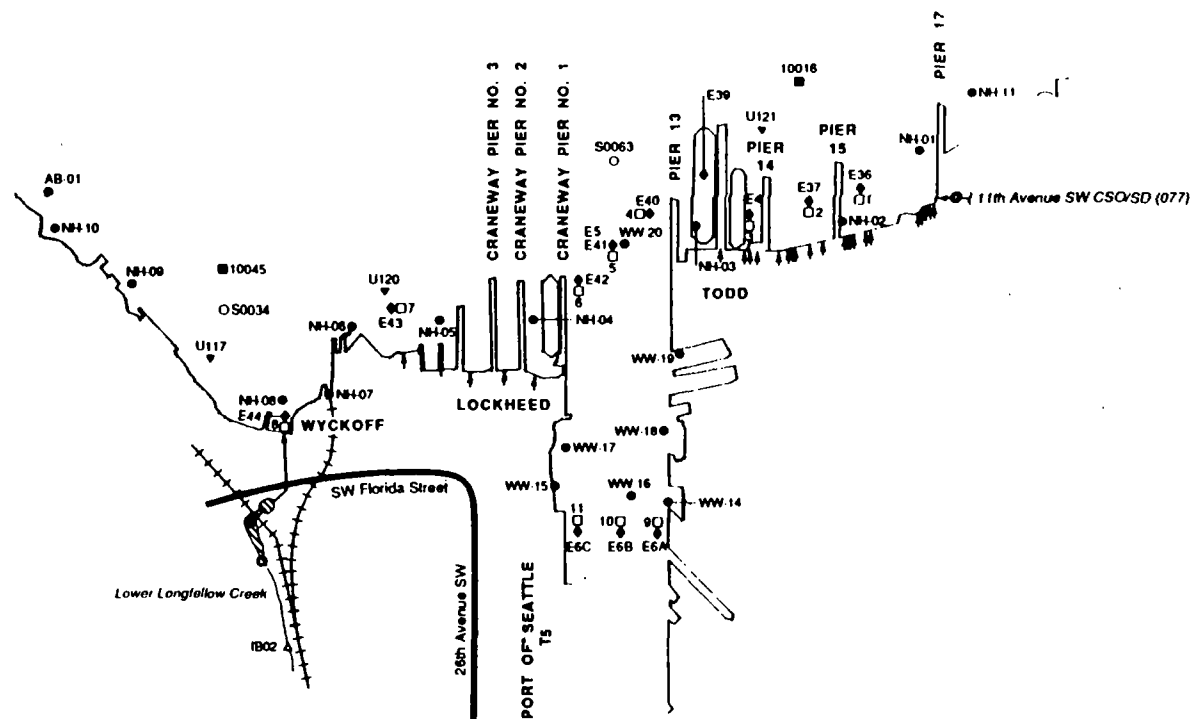


Figure 4-10. Locations of offshore and drain sampling stations, CSOs, and storm drains in the North Harbor Island study area.

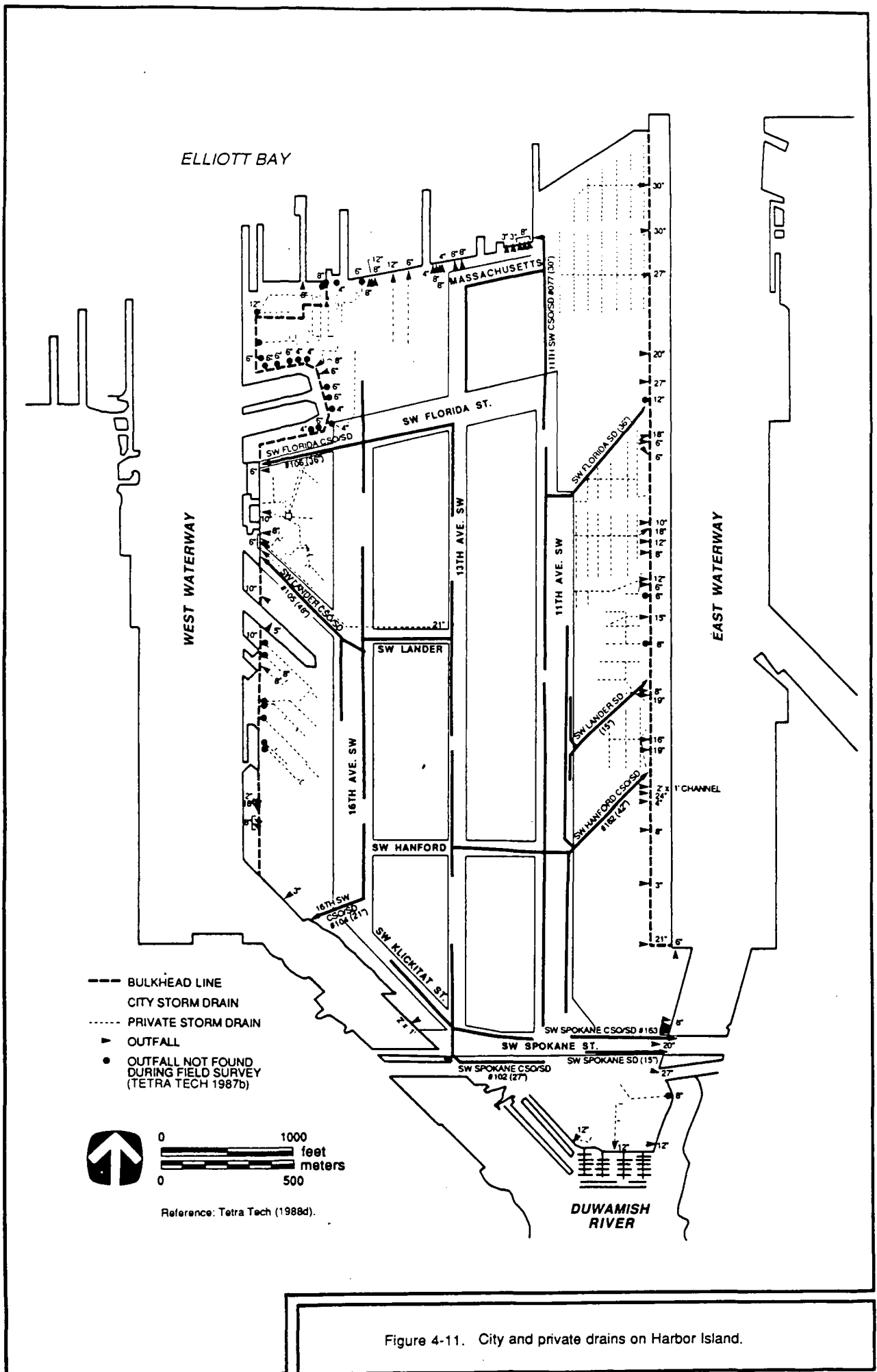
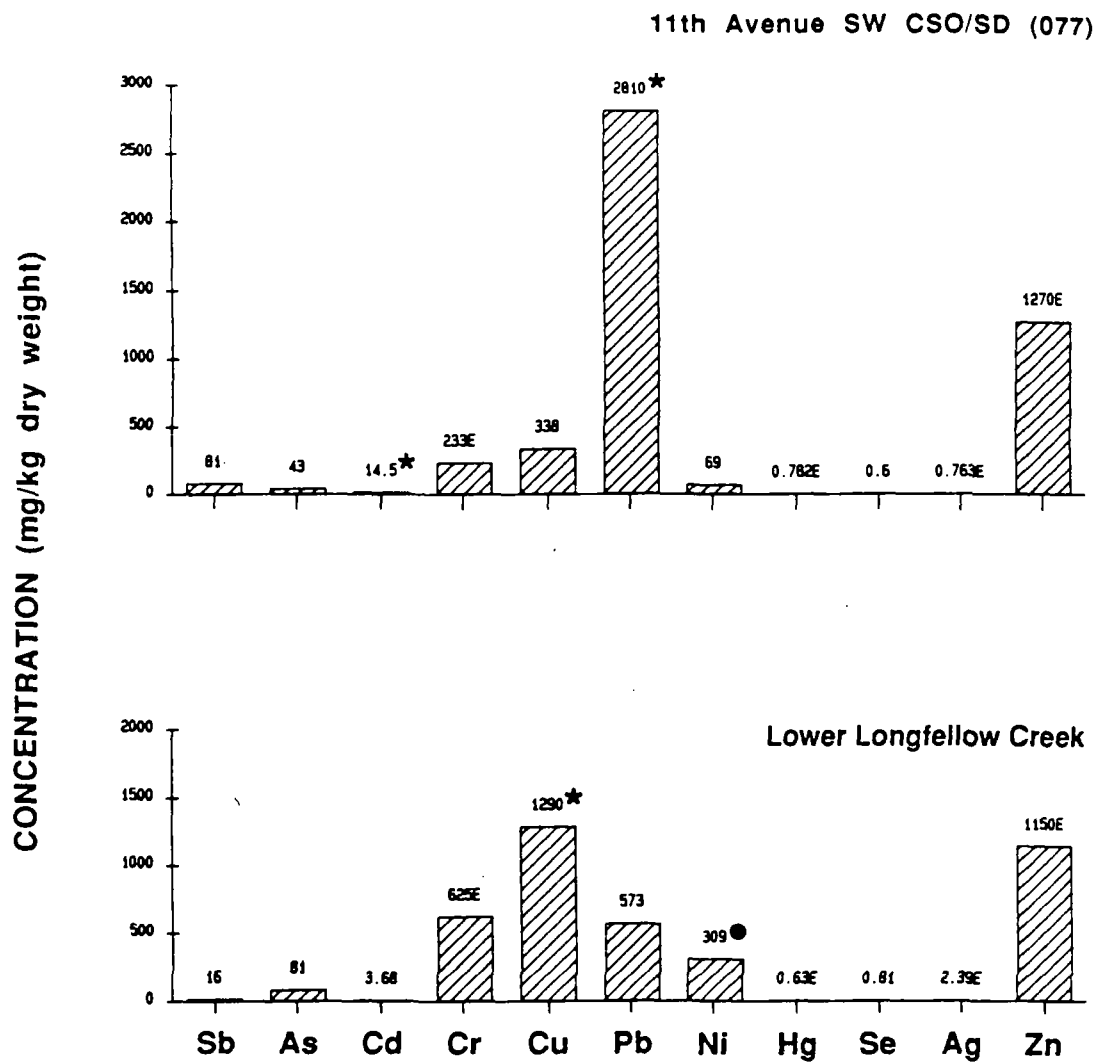


Figure 4-11. City and private drains on Harbor Island.



LEGEND

★ EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-12. Concentrations of metals in sediments collected from drains discharging into the North Harbor Island study area.

metals. Sediment from the 11th Ave. SW CSO/SD (077) exceeded HAET for lead and cadmium. Sediment from lower Longfellow Creek exceeded HAET for copper and the 90th percentile concentration for nickel.

The relative distribution of metals in the 11th Ave. SW CSO/SD (077) sediment sample is shown in Table 4-5. Lead (58 percent) comprised the greatest proportion of metals in the sediment. The 11th Ave. SW CSO/SD (077) serves a 37-ac area located in the northeast corner of Harbor Island (see Map 3 in Map Appendix). This area is currently occupied by a tugboat company, the Port of Seattle, and several bulk petroleum storage facilities. Few sources of lead in the basin have been documented. The primary uses of lead are in storage batteries; as an anti-knocking compound in leaded gasoline; in pigments, solders, plumbing, cable covering, and bearings; and in caulking (Kirk-Othmer 1985). Additional uses are provided in Appendix H. The bulk petroleum storage facilities may be a potential source of lead in the basin. In the past, it was common practice to dispose of leaded tank sludge onsite (i.e., landfarming). Sludge landfarming has been documented at one of the storage facilities (Cargill, D., 10 May 1988, personal communication).

Cadmium is primarily used as an electroplated coating on steel and cast iron parts for corrosion protection, in brazing and alloys, in solders, and as a hardener for copper (Kirk-Othmer 1985) (see Appendix H). Specific sources of cadmium in the basin have not been documented in the 11th Ave. SW CSO/SD (077). There are two facilities in the basin that are included in CERCLIS: a tugboat company and a bulk petroleum storage facility (U.S. EPA, 22 October 1987, personal communication). Surface water, groundwater, and soil contamination has been observed at the bulk petroleum storage facility. Further site inspections have been recommended for the tugboat facility by U.S. EPA.

Lower Longfellow Creek, which serves approximately 120 ac in West Seattle (see Map 3 in Map Appendix), discharges into the North Harbor Island study area. Flow from the upper portion of the Longfellow Creek basin (1,400 ac) is diverted at SW Anderson St. to the West Waterway via SW Hinds CSO/SD (099). However, under high flow conditions, discharge from the upper

TABLE 4-5. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS
FROM DRAINS DISCHARGING INTO THE NORTH HARBOR ISLAND STUDY AREA

Metals	11th Ave. SW CSO/SD (077) ^a	Lower Longfellow Creek ^a	Outfall of Lower Longfellow Creek ^b	Pond Outlet ^b	Pond Inlet ^b	NPDES Pond Outlet ^b	Street Dust ^c
Antimony	2	<1	<1	<1	<1	<1	<1
Arsenic	1	2	2	2	2	<1	1-5
Cadmium	<1	<1	<1	<1	<1	<1	<1
Chromium	5	15	16	6	8	4	2-15
Copper	7	32	28	35	30	19	4-12
Lead	58	14	6	16	15	24	30-64
Mercury	<1	<1	<1	<1	<1	<1	<1
Nickel	1	8	10	8	8	6	2-4
Silver	<1	<1	<1	<1	<1	<1	<1
Zinc	26	28	39	34	38	45	14-54
Total metals (mg/kg)	4,840 ^d	4,040 ^d	900 ^d	3,500 ^d	1,650 ^d	2,660 ^d	680-1,800 ^e

^a Elliott Bay Action Program stations.

^b Fuentes, R., 21 April 1988, personal communication (samples from 8/85).

^c Commercial and industrial sites (Galvin and Moore 1982).

^d Values reported as dry-weight concentrations.

^e Street dust values reported as wet-weight concentrations, with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

basin may overtop the diversion structure, flood property north of SW Andover St., and reach the North Harbor Island study area via lower Longfellow Creek. The diversion structure at SW Andover St. was constructed in 1974. Prior to 1974, the entire Longfellow Creek drainage basin (1,500 ac) discharged to the North Harbor Island study area. In addition, three city CSOs (168, 169, and 170) discharged into Longfellow Creek in the past. These three CSOs were eliminated with the implementation of the city's 1980 CSO control plan (Corson, C., 6 May 1988, personal communication). Lower Longfellow Creek also receives NPDES-permitted discharges from Seattle Steel (see Table 2-4). However, during periods of high flow, runoff from the upper basin may overstep the diversion structure and discharge to the North Harbor Island study area.

The lower end of Longfellow Creek flows through a series of ditches, pipes, and ponds prior to discharging into Elliott Bay (see Figure 4-10). During the source sampling effort, a sample was collected on a bank near the influent pipe on the upstream side of a pond that is located about 500 ft south of SW Florida St. The pond receives runoff from the area west of the pond (currently occupied by a scrap yard), as well as NPDES-permitted discharges from Seattle Steel. Copper and zinc were the metals with the greatest relative abundance in the sample (see Table 4-5). Concentrations of copper and nickel in the sediments (see Figure 4-12) generally exceeded the concentrations reported in urban street dust (see Table 4-2) by 1 order of magnitude. Similar results were obtained during U.S. EPA sampling conducted in August 1985 (Fuentes, R., 21 April 1988, personal communication). U.S. EPA collected sediment samples from several locations in the same pond on the south side of SW Florida St. that was sampled in this study, and from a pond further upstream that receives NPDES discharges from Seattle Steel prior to discharge into the lower Longfellow Creek system. The relative distribution between the metals in the two ponds was similar.

Potential contaminant sources in the drainage basin include the West Seattle landfill (Seattle-King County Department of Public Health 1984) and a steel manufacturer (Seattle Steel) that is included on CERCLIS (U.S. EPA, 22 October 1987, personal communication) because of observed soil, groundwater, and storm drain contamination. The West Seattle landfill operated

between 1939 and 1966 and received primarily residential garbage (Seattle-King County Department of Public Health 1984). At one time, Longfellow Creek ran directly through the landfill. The creek is currently routed through the area in a pipe and does not come in direct contact with landfill materials. Infiltration of contaminated groundwater is a potential contaminant pathway to lower Longfellow Creek.

Organic Compounds--

Selected organic compounds measured in the sediments collected from the two drains discharging into the North Harbor Island study area are presented in Figure 4-13. PAH compounds, 4-methylphenol, p,p'-DDT, and PCBs were identified as problem chemicals in these two drains:

- 11th Ave. SW CSO/SD (077) - fluoranthene, and indeno(1,2,3-c,d)pyrene
- Lower Longfellow Creek - 4-methylphenol, p,p'-DDT, and PCBs.

The 11th Ave. SW CSO/SD (077) basin is occupied by several bulk petroleum storage facilities and a railroad transshipment area. Spills and leaks from the railcars would be transported via stormwater runoff to catch basins and storm drains in the area (Cargill, D., 10 May 1988, personal communication). The railroad tracks may have served as a conduit for contaminants to Elliott Bay.

PAHs are components of fossil fuels and may be formed during any combination process (see Appendix H). The relatively high ratio of HPAH to LPAH in the drain sediments (8:1) suggests that the source of PAH contamination may be combustion-related. HPAH compounds are typically characteristic of combusted fuel materials (Lee et al. 1977). Further investigation of this area is required to determine whether the PAH contamination is from historic or ongoing sources, and to establish transport pathways (e.g., surface water or groundwater).

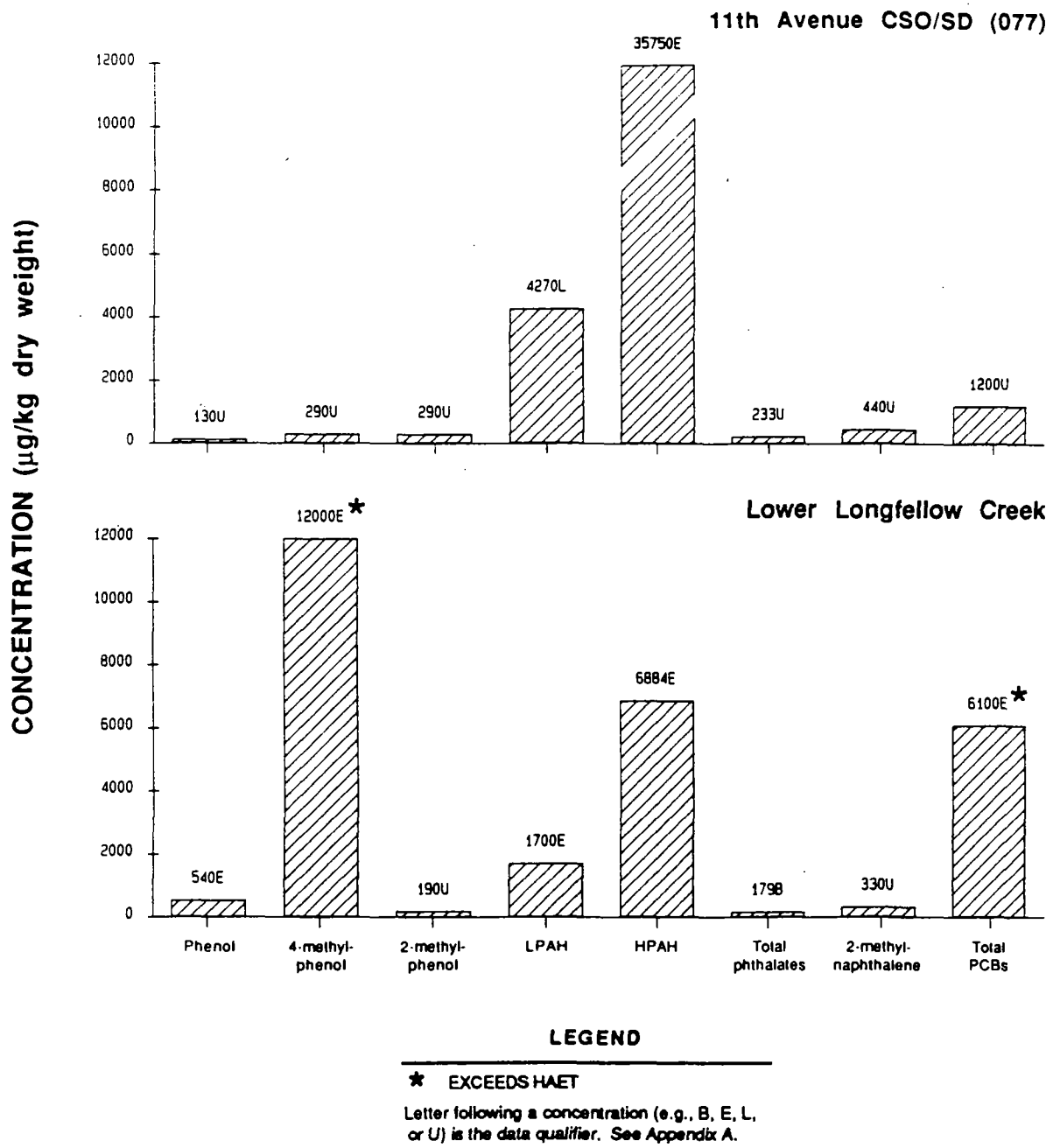


Figure 4-13. Concentrations of selected organic compounds in sediments collected from drains discharging into the North Harbor Island study area.

4-Methylphenol, HPAH, and PCBs are the primary extractable organic compounds in the lower Longfellow Creek sediment sample. In addition, p,p'-DDT, although not a major component of the sample (680 ug/kg), exceeded the HAET. Uses of 4-methylphenol are presented in Appendix H. There are no documented sources of 4-methylphenol in the lower Longfellow Creek basin. However, the inactive West Seattle landfill may be a potential source due to the wide variety of materials that were disposed of there.

p,p'-DDT is an insecticide that was used extensively in the U.S. prior to 1973. Historical uses of p,p'-DDT are summarized in Appendix H. It is extremely persistent in the environment due to its resistance to destruction by light and oxidation. In addition, p,p'-DDT can bioaccumulate (Kirk-Othmer 1985). In 1973, p,p'-DDT use was restricted to applications essential to public health because of widespread environmental contamination (Kirk-Othmer 1985). Because of its widespread use, there are probably numerous sources of p,p'-DDT in the lower Longfellow Creek basin, including the West Seattle landfill and past residential applications. Continuing use of p,p'-DDT purchased prior to 1973 may represent an ongoing source of contamination.

Lower Longfellow Creek drains portions of the scrap yard that Metro (Hubbard and Sample 1988) identified as the source of PCBs in the SW Florida CSO/SD (see Map 3 in Map Appendix). In August 1985, U.S. EPA collected sediment samples from the area where runoff from the scrap yard appeared to enter the pond on lower Longfellow Creek, as well as from areas upstream of the pond at the Seattle Steel NPDES-discharge point (Fuentes, R., 21 April 1988, personal communication). There were different Aroclor mixtures in the samples collected from lower Longfellow Creek than were reported by Metro for SW Florida CSO/SD (098) (Table 4-6). PCBs in the samples from the SW Florida CSO/SD (098) were composed of 81 percent Aroclor 1260, 17 percent Aroclor 1254, and 1 percent each of Aroclor 1248 and 1242. Total PCBs in the sediment samples from lower Longfellow Creek contained primarily Aroclor 1248 (85-94 percent) and Aroclor 1260 (6-15 percent). This difference in the composition of the PCB contamination indicates that there may have been several PCB sources in the lower Longfellow Creek basin. Specific uses of individual Aroclors are presented in Appendix H.

TABLE 4-6. SUMMARY OF PCBs (UG/KG) MEASURED IN SEDIMENTS FROM LOWER LONGFELLOW CREEK AND SW FLORIDA CSO/SD (098) DRAINS

Drains	1016	1221	1232	1242	1248	1254	1260	total PCB
SW Florida CSO/SD (098) ^a	ND ^b	ND	ND	9,500	9,500	170,000	810,000	999,000
Pond Inlet ^c	U60 ^d	U60	U60	U60	4,640	U60	3,500	8,140
Pond Inlet ^c	U240	U240	U240	U240	17,700	U240	1,220	18,920
NPDES Pond Outlet ^c	U50	U50	U50	U50	9,400	U50	560	9,960
Outfall of Longfellow Creek	U25	U25	U25	U25	2,280	U25	400	2,680

^a Sample, T., 23 October 1987, personal communication (samples from 10/84).

^b ND = Not detected.

^c Fuentes, R., 21 April 1988, personal communication (samples from 8/85).

^d U = Undetected at concentration shown.

4.3.5 East Waterway

Sediment samples were collected from all seven CSOs and the majority of city storm drains that discharge into the East Waterway (Figure 4-14). Three small city storm drains (i.e., Massachusetts, SW Spokane, and S. Stacy) were not sampled because of insufficient sediment in the lines or the inability to locate or open the manholes to access the drain.

Metals--

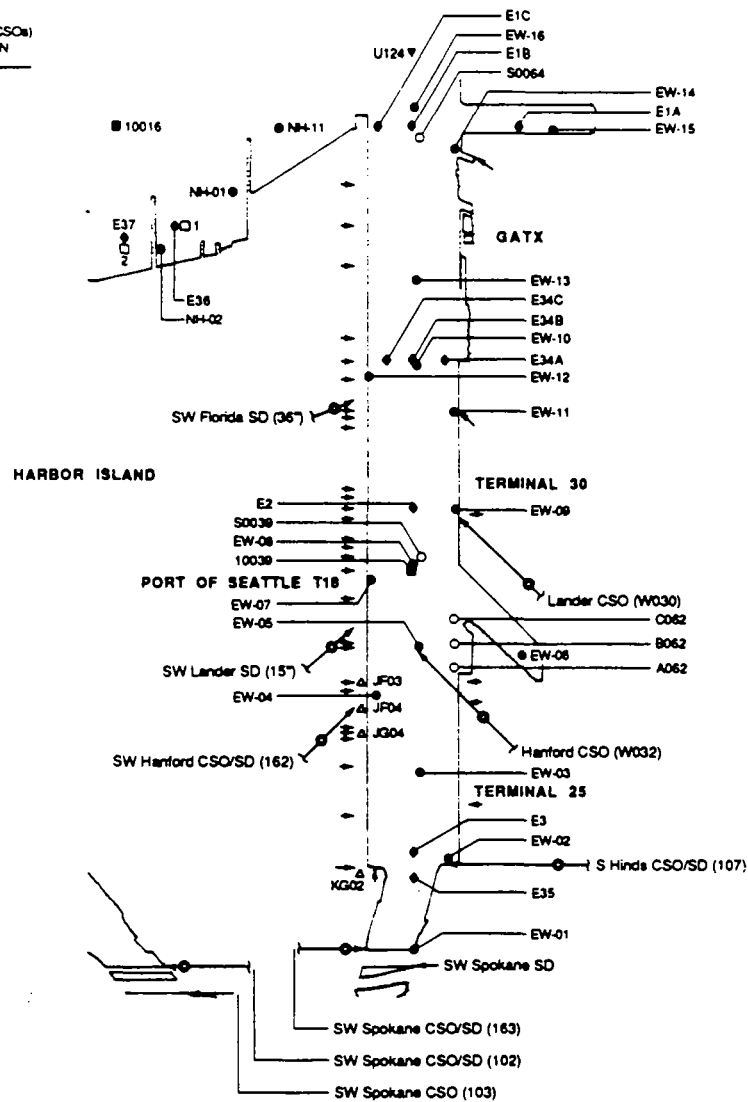
Results of the metals analyses from these drain sediments are summarized in Figure 4-15. There were no exceedances of HAETs for metals in the SW Florida SD (36 in) or the SW Lander SD (15 in). Both of these drains serve the Port of Seattle property on the east side of Harbor Island (Terminal 18). Most of Terminal 18 is paved and used for containerized shipping.

Lead and cadmium were the most common problem chemicals in the five remaining drains sampled in the East Waterway. Lead exceeded the HAET (700 mg/kg) in the SW Hanford CSO/SD (162), SW Spokane CSO/SD (163), and S. Hinds CSO/SD (107) (Figure 4-15). Cadmium exceeded the HAET (9.6 mg/kg) in the SW Spokane CSO/SD (163) and Lander CSO (W030). In addition, selenium exceeded the 90th percentile concentration (2.6 mg/kg) in two drains: SW Hanford CSO/SD (162) and SW Spokane CSO/SD (163). Mercury exceeded the HAET (1,600 mg/kg) in sediments from the Hanford CSO (W032), and zinc exceeded the HAET in sediments from the SW Hanford CSO/SD (162).

Lead concentrations in the sediments from the Hanford CSO/SD (162) (3,090 mg/kg) and SW Spokane CSO/SD (163) (3,000 mg/kg) were similar. Elevated lead concentrations in these two drains may have been related to historic emissions from the secondary lead smelter on Harbor Island. The Hanford CSO/SD basin is located immediately east of the smelter area. Although the City of Seattle paved most of the parking lots on Harbor Island to alleviate the lead problem caused by fugitive dust emissions (Hubbard and Sample 1988), the data reported herein, particularly the results from the Lander CSO/SD (105) (see below) indicate that lead contamination is a continuing problem.

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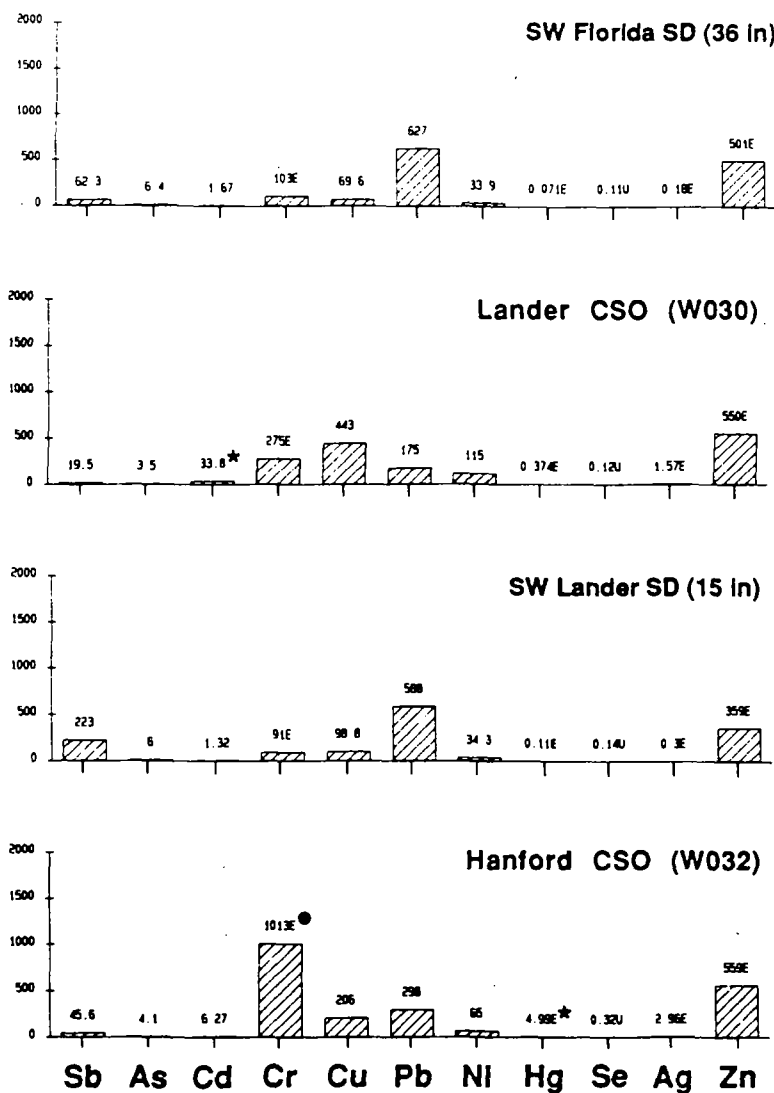
- TETRA TECH (THIS STUDY)
- ▲ METRO (1987)
- GAMPONIA ET AL (1986)
- ROMBERG ET AL (1984)
- ▼ STÖBER AND CHEW (1984)
- ◆ U.S. EPA (1982, 1983)
- MALINS ET AL (1980, 1982)
- TETRA TECH SOURCE SAMPLING STATION
- ▲ METRO SOURCE SAMPLING STATION
- SOURCE (INCLUDES STORM DRAINS AND CSOs) DISCHARGE LOCATION



0 1000 feet
0 300 meters

Figure 4-14. Locations of offshore and drain sampling stations, CSOs, and storm drains in the East Waterway study area.

CONCENTRATION (mg/kg dry weight)



LEGEND

★ EXCEEDS HAET

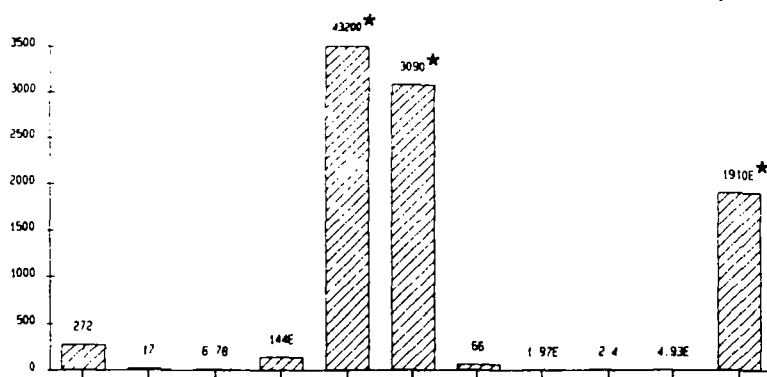
● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

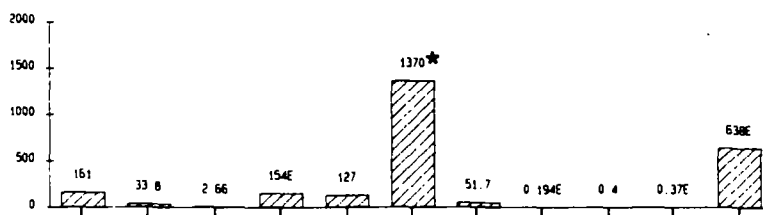
Figure 4-15. Concentrations of metals in sediments collected from drains discharging into the East Waterway study area.

CONCENTRATION (mg/kg dry weight)

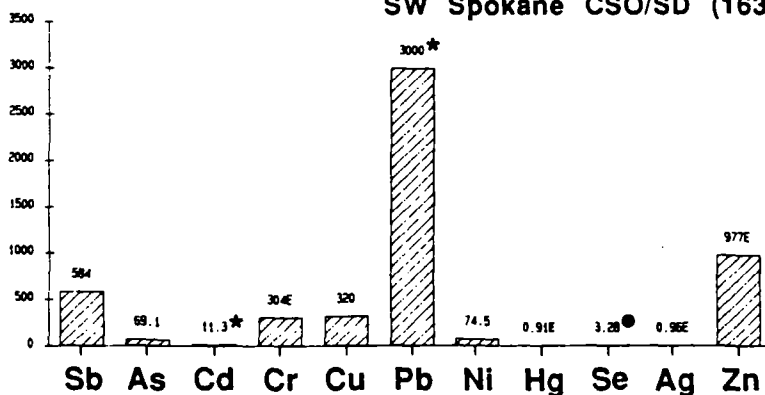
SW Hanford CSO/SD (162)



S Hinds CSO/SD (107)



SW Spokane CSO/SD (163)



LEGEND

★ EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-15. (Continued).

There are also numerous metal scrap yards and metal plating facilities in the SW Hanford CSO/SD (162) basin (see Map 4 in Map Appendix) that could be contributing lead to the drain. Uses of lead and lead compounds are summarized in Appendix H. Three facilities, a metal plater (Value Metal Plating), an iron processing and iron recycling facility (Seattle Iron and Metals), and a scrap metal dealer and foundry (Non-Ferrous Metals) have been included on Ecology's list of hazardous waste sites as high priorities for metals contamination (WEC Alert! 1987).

Metro collected a sediment sample from a catch basin connected to the SW Hanford CSO/SD (162) at the Non-Ferrous Metals facility on 17 July 1984 and found elevated concentrations of lead (44,000 mg/kg; Sample, T., 23 October 1987, personal communication). The yard at Non-Ferrous Metals is swept once a week, and the catch basin is cleaned twice a year (Hubbard, T., 26 November 1984, personal communication). Because of the elevated concentrations of metals found in the catch basin sediments, Metro recommended that Non-Ferrous Metals install a settling pond to prevent contaminated sediments from entering the storm drain system.

Two other facilities in the SW Hanford CSO/SD (162) drainage basin have been identified as potential sources of lead. Ecology reported that Golden Penn, a waste oil recycler had stored batteries onsite (Dorigan, L., 30 June 1987, personal communication). During a December 1985 inspection of the Seattle Iron and Metals facility, Ecology reported that batteries were stored outside on broken pallets on an unbermed asphalt surface (Ecology 1987). Storage batteries are a potential source of lead.

The SW Spokane CSO/SD (163) serves a relatively small basin (4 ac) located in the southeast corner of Harbor Island (see Map 3 in Map Appendix). The distribution of metals in SW Spokane CSO/SD (163) sediments was similar to that in street dust (Table 4-7). With the exception of zinc, the concentrations of all metals in the SW Spokane CSO/SD (163) (5,300 mg/kg) were higher than the concentrations reported in street dust from industrial/commercial areas (700-1,800 mg/kg). This difference may have been due

TABLE 4-7. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS FROM DRAINS DISCHARGING INTO THE EAST WATERWAY STUDY AREA

Metals	SW Lander SD (15 in)	SW Florida SD (36 in)	Lander CSO (W030)	Hanford CSO (W032)	S. Hinds CSO/SD (107)	SW Spokane CSO/SD (163)	Hanford CSO/SD (162)	Street Dust ^a
Antimony	16	4	1	2	6	11	<1	<1
Arsenic	<1	<1	<1	<1	1	1	<1	1-5
Cadmium	<1	<1	2	<1	<1	<1	<1	<1
Chromium	6	7	17	46	6	6	<1	2-15
Copper	7	5	27	9	5	6	89	4-12
Lead	42	45	11	14	54	56	0.6	30-64
Nickel	2	2	7	3	2	1	<1	2-4
Mercury	<1	<1	<1	<1	<1	<1	<1	<1
Silver	<1	<1	<1	<1	<1	<1	<1	<1
Zinc	26	36	34	25	25	18	4	14-54
Total Metals (mg/kg)	1,400 ^b	1,400 ^b	1,600 ^b	2,200 ^b	2,500 ^b	5,300 ^b	48,700 ^b	280-1,800 ^c

^a Commercial and industrial sites (Galvin and Moore 1982).

^b Values reported as dry-weight concentrations.

^c Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

to the presence of heavy industry in the SW Spokane CSO/SD (163) drainage basin.

Other drains in the East Waterway study area in which the relative distributions of metals in the sediments were similar to those in street dust included the SW Lander SD (15 in), SW Florida SD (36 in), and S. Hinds CSO/SD (107) (see Table 4-7). This similarity suggests that metals contamination in these drains may have been from nonpoint sources (e.g., urban runoff). Sediments from the S. Hinds CSO/SD (107) also exceeded the HAET for lead, but the concentration was about 3 times lower than the lead concentrations measured in the SW Hanford CSO/SD (162) and SW Spokane CSO/SD (163).

Concentrations of copper in the sediments from the SW Hanford CSO/SD (162) (43,200 mg/kg) exceeded the HAET (800 mg/kg), with copper constituting 89 percent of the total metals evaluated (sum of antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) in the drain sediments. The concentration of copper in the SW Hanford CSO/SD (162) was 1-3 orders of magnitude greater than the concentration measured in other drains in the study area. Copper is used primarily as an electrical conductor; approximately 50 percent of the U.S. demand for copper is for electrical use (Kirk-Othmer 1985). Copper has also been used for domestic water pipes, in automobile radiators, and as a antifoulant in marine paints (see Appendix H).

There are several potential sources of copper in the SW Hanford CSO/SD (162) basin. Metro has identified the Seattle Iron and Metals metal recycling facility as a major source of copper in the SW Hanford CSO/SD (162) basin (Hubbard, T., 23 April 1984, personal communication). Seattle Iron and Metals operates a copper incinerator to burn insulation off of copper wire. In the past, the copper was rinsed with water after incineration. The ash and scale were collected in a settling pond onsite. Metro has reported that occasionally the settling pond overflowed into the SW Hanford CSO/SD (162) (Hubbard, T., 23 April 1984, personal communication). In addition, the settling pond has received stormwater runoff from a trough adjacent to the aluminum remelt furnace. In 1984, Metro sampled water in the pond and in the drain. Copper concentrations in the pond and drain

ranged between 18 and 250 mg/L (Sample, T., 23 October 1987, personal communication). The Seattle Iron and Metals facility has been included on Ecology's list of hazardous waste sites as a high priority because of metals contamination (WEC Alert! 1987).

Non-Ferrous Metals has also been identified as a source of copper in the SW Hanford CSO/SD (162) basin. In 1984, Metro found copper at 5,000 mg/kg in the sediment collected from a catch basin at Non-Ferrous Metals (Sample, T., 23 October 1987, personal communication). Non-Ferrous Metals has also been included on Ecology's list of hazardous waste sites as a high priority because of metals contamination (WEC Alert! 1987).

Value Metal Plating has been identified as another source of copper in the SW Hanford CSO/SD (162) basin. The facility reportedly discharged process wastewater on the ground behind their facility from 1970 until 1978, when the facility connected to the sanitary sewer system (Black & Veatch 1985). In December 1977, copper was measured in their effluent at 55 mg/L (Sweet-Edwards & Associates and Harper-Owes 1985).

The cadmium concentration measured in the Lander CSO (W030) (33.8 mg/kg) was one of the highest concentrations measured in the source study. Uses of cadmium are presented in Appendix H. There is one metal plating facility and one metal recycling facility operating in the Lander CSO (W030) service area. The metal plating facility is regulated under an industrial pretreatment permit from Metro (Hildebrand, D., 16 October 1987, personal communication). Discharge from this facility is monitored periodically by Metro. The cadmium concentrations for the period May 1985 to April 1986 ranged from 0.02 mg/L to 0.4 mg/L (Hildebrand, D., 16 October 1987, personal communication).

Selenium measured in the sediments from the SW Hanford CSO/SD (162) (2.9 mg/kg) and SW Spokane CSO/SD (163) (3.28 mg/kg) exceeded the 90th percentile concentration (2.6 mg/kg). Selenium is a common component of the earth's crust. The average concentration of selenium in soils in the U.S. is approximately 0.3 mg/kg, with a range of less than 1 to 3.5 mg/kg (Kirk-Othmer 1985). The concentrations found in the sediments from these two

drains (2.9-3.3 mg/kg) were greater than the average concentration in soil and the concentrations reported in Puget Sound reference area sediments (0.1-1.0 mg/kg). Selenium is used in the production of ferrous metals, copper and copper alloys, nickel-iron and cobalt-iron alloys, lead and lead alloys, and chromium plating (see Appendix H). In addition, selenium and its compounds are used in photoelectric cells, photovoltaic cells, rectifiers, and in xerography (Kirk-Othmer 1985). Consequently, the selenium contamination in the Hanford CSO/SD (162) and SW Spokane CSO/SD (163) may have been caused by the same kinds of sources responsible for copper and lead contamination observed in these two drains.

Sediments from the Hanford CSO (W032) exceeded the HAET for chromium and mercury (see Figure 4-15). The chromium concentration (E1,013 mg/kg) was the highest concentration measured during the sampling effort. Chromium is primarily used in metal finishing to provide a more decorative and corrosion resistant surface. In addition, chromium is used in alloys, pigments, and allied products; leather tanning and textiles; wood preservation; and as a catalyst and in chemical intermediates (Kirk-Othmer 1985). Mercury is used in batteries, electrical lamps, and in industrial control instruments such as thermometers, manometers, gauges, and valves (Kirk-Othmer 1985).

The SW Hanford CSO (W032) serves approximately 255 ac of primarily industrial property in South Seattle (see Map 2 in Map Appendix). No specific sources of chromium have been documented in the area. Potential sources in the basin include a metal finisher and manufacturer of janitorial supplies that are permitted to discharge wastes to the sanitary sewer under Metro's industrial pretreatment program (Hildebrand, D., 16 October 1987, personal communication).

Other potential sources of chromium include a settling pond that received cooling water and truck washwater from a cement manufacturer (RGS, 13 June 1985, personal communication), and a marine salvage company that has been included on CERCLIS by the U.S. EPA (U.S. EPA, 22 October 1987, personal communication). Both industrial pretreatment facilities are considered major dischargers by Metro (Hildebrand, D., 23 December 1987, personal communication). During the period from May 1985 through April

1986, the concentration of chromium in the discharges from these two facilities ranged from 0.74 to 1.24 mg/L in the metal finisher's wastes and 0.08 to 0.56 mg/L in the janitorial supplier's wastes. The cement manufacturer, located on the south edge of the Hanford CSO (W032) service area, has been identified as a potential source of chromium (RGS, 13 June 1985, personal communication). Chromium and copper were found in sediments collected from the settling pond. Based on available information, it appears that infiltration of groundwater is the only pathway to the Hanford CSO (W032) from this facility. The marine salvage company is classified as a treatment, storage, and disposal (TSD) facility. Wastes containing heavy metals have been observed at this site (U.S. EPA, 22 October 1987, personal communication).

The concentration of mercury exceeded the HAET (2.1 mg/kg) in the sediment from the Hanford CSO (W032) (see Figure 4-15). Mercury is used in agricultural pesticides, as a catalyst in the production of urethane foams, in electrical apparatus (e.g., batteries and electrical lamps), and in industrial control instruments (e.g., thermometers, barometers, and manometers), and other pressure-sensing instruments such as gauges, valves, seals, and navigational devices (Kirk-Othmer 1985). Because of the general industrial nature of the Hanford CSO service area, it is not possible to identify specific sources of mercury. Further investigation of potential sources in the area is required.

The concentration of zinc in the sediment collected from the SW Hanford CSO/SD (162) (see Figure 4-15) exceeded the HAET (1,600 mg/kg). The zinc concentration in the SW Hanford CSO/SD (162) (1,910 mg/kg) was 2-5 times greater than concentrations measured in the sediments collected from other drains in the East Waterway (359-977 mg/kg). Zinc is used in metallic coatings, metal alloys, dye casting, electrical batteries, and antifoulant paints (see Appendix H).

Discharges from the Seattle Iron and Metals facility have been identified as a source of zinc. Concentrations of zinc measured in the discharge from the copper incinerator on 20 March 1984 ranged from 1,200 to 13,000 ug/L (Sample, T., 23 October 1987, personal communication).

Non-Ferrous Metals has also been identified as a source of zinc in the SW Hanford CSO/SD (162) basin. Sediment collected from a catch basin on the property contained 10,000 mg/kg of zinc (Sample, T., 23 October 1987, personal communication). In addition, Ecology reported that Non-Ferrous Metals discharged cooling water from their facility directly onto the ground prior to 1986 when a closed-loop water cooling system was installed. A soil sample collected in April 1986 at the discharge site was analyzed in triplicate by the laboratory and contained 1,074-1,285 mg/kg of zinc (Dorigan, L., 4 April 1986, personal communication). Zinc (6.3 mg/L) was also found in a wastewater sample from Value Metal Plating (Sweet-Edwards & Associates and Harper-Owes 1985). Value Metal Plating reportedly discharged process wastewater onto the ground behind their facility from 1970 until 1978 (Black & Veatch 1985). There are likely other potential sources of zinc in the basin including scrap metal dealers and metal finishers.

Organic Compounds--

Selected extractable organic compounds in the drains discharging into the East Waterway are summarized in Figure 4-16. PAH, phthalates, PCBs, chlorinated benzenes, p,p'-DDT, and alkylated phenols were the problem chemicals identified in these drains:

- SW Florida SD (36 in) - p,p'-DDT
- SW Lander SD (15 in) - dimethyl phthalate
- SW Hanford CSO/SD (162) - 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, 1-methylphenanthrene, chlorobenzenes, and PCBs
- Hanford CSO (W032) - 4-methylphenol, 2-methylnaphthalene, and butyl benzyl phthalate.

There were no organic compound exceedances of HAET or 90th percentile concentration in the sediments collected from the SW Spokane CSO/SD (163), S. Hinds CSO/SD (107), or the Lander CSO (W030).

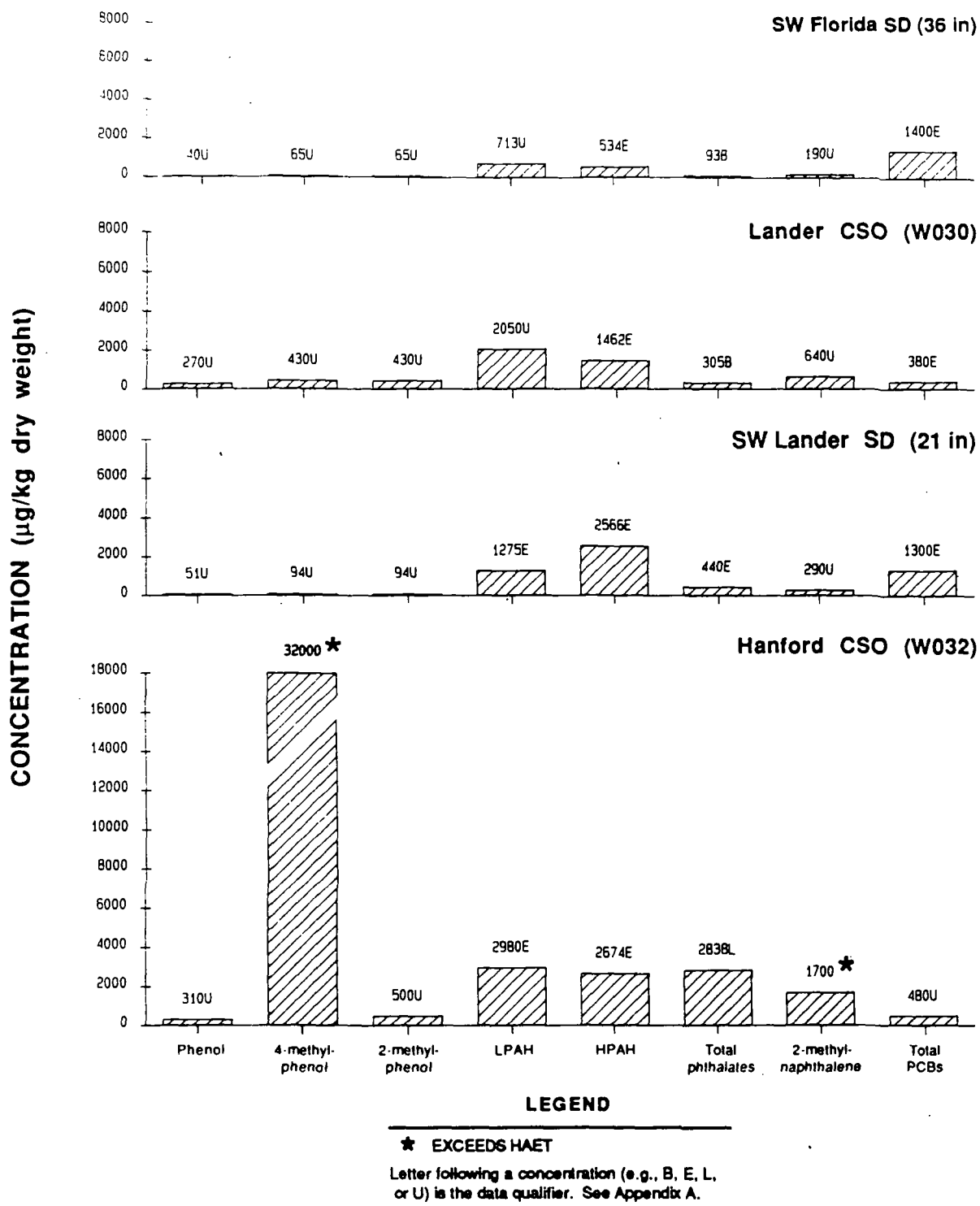
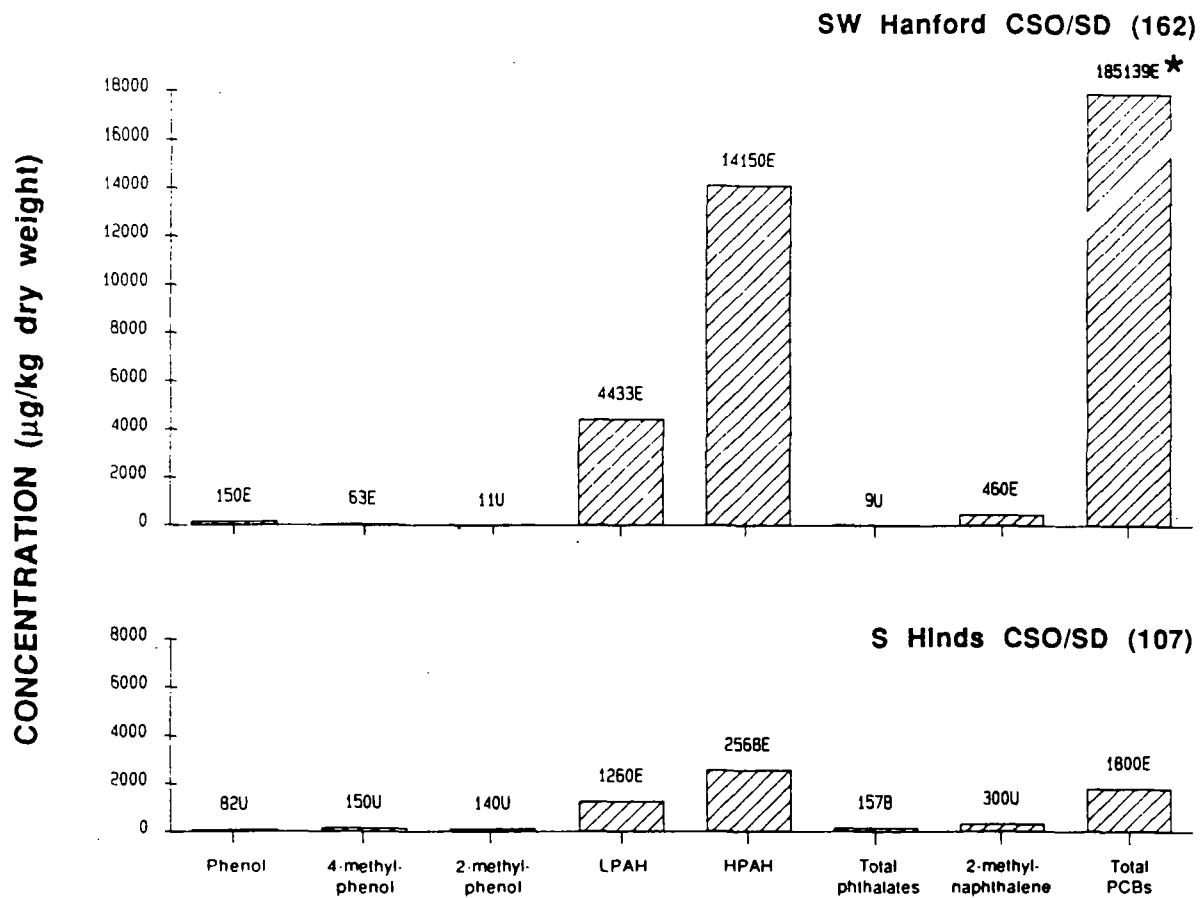


Figure 4-16. Concentrations of selected organic compounds in sediments collected from drains discharging into the East Waterway study area.



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., B, E, L, or U) is the data qualifier. See Appendix A.

Figure 4-16. (Continued).

p,p'-DDT concentrations in the sediments from the SW Florida SD (36 in) exceeded the HAET. p,p'-DDT was undetected in the other drains in the East Waterway. However, the detection limit for the Hanford CSO/SD (162) samples (81 ug/kg) exceeded the HAET (11 ug/kg). As was explained earlier, p,p'-DDT was a widely used pesticide in the U.S. prior to 1973 (see Appendix H). However, use declined after 1973 when p,p'-DDT was restricted because of environmental hazards (Kirk-Othmer 1985). There are no documented sources of p,p'-DDT in the SW Florida SD (36 in) basin. SW Florida SD serves approximately 25 ac, including portions of Terminal 18 and a petroleum pipeline facility on Harbor Island (see Map 3 in Map Appendix). Terminal 18 currently functions as a container terminal. Because p,p'-DDT is currently restricted, p,p'-DDT contamination in the SW Florida SD (36 in) may have been caused by past use or spills.

HAETs for phthalates were exceeded in the SW Lander SD (15 in) (dimethyl phthalate) and the Hanford CSO (W032) (butyl benzyl phthalate) sediments. Uses of phthalates are presented in Appendix H. There are no documented sources of phthalates for either of these two drains. The Lander SD (15 in) serves approximately 8 ac of the container area on Terminal 18. The Hanford CSO (W032) serves a large area (255 ac; see Map 2 in Map Appendix) on the east side of the East Waterway. Most of the Hanford CSO (W032) basin consists of commercial and industrial property. One potential source of phthalates in the Hanford CSO (W032) basin may be the inactive 6th Ave S. landfill (see Map 4 in Map Appendix). Although little is known about this landfill, it is reported to have operated for approximately 30 yr, receiving dredged material from the Duwamish River, as well as municipal garbage (Seattle-King County Department of Public Health 1984). There have been recent complaints from property owners in the area concerning odors. The infiltration of potentially contaminated groundwater from the landfill is a potential transport pathway into the Hanford CSO (W032).

Other chemicals that exceeded HAET in the Hanford CSO (W032) included 4-methylphenol and 2-methylnaphthalene (see Figure 4-16). Uses of 4-methylphenol are presented in Appendix H. The landfill may have contributed to the 4-methylphenol contamination found in the Hanford CSO (W032), because

concentrations of 4-methylphenol and phthalate concentrations were elevated in the sediments from the Diagonal Way CSO/SD (111), which also serves portions of the old 6th Ave. S. landfill.

2-Methylnaphthalene is a PAH commonly found in used crankcase oil (Peake and Parker 1980). In addition, it was one of the more frequently detected organic compounds in the drain sediments (52 percent of the samples). The elevated concentrations of 2-methylnaphthalene in the sediments from the Hanford CSO (W032) indicate that spills or improper disposal of crankcase oil or other petroleum products may be potential sources in the basin.

Chlorinated benzene (1,4-dichlorobenzene and 1,2,4-trichlorobenzene), PAH (1-methylphenanthrene), and PCB concentrations in the sediment from the SW Hanford CSO/SD (162) exceeded HAET concentrations. 1,4-Dichlorobenzene and 1,2,4-trichlorobenzene are used as solvents (Kirk-Othmer 1985). 1,4-Dichlorobenzene is also used in air deodorants, insecticides, moth repellants, polyphenylene sulfide resin, dye intermediates, and pharmaceuticals (see Appendix H). 1,2,4-Trichlorobenzene is used in dye carriers, herbicide intermediates, heat transfer mediums, dielectric fluids in transformers, degreasers, lubricants, and in insecticides (Kirk-Othmer 1985) (see Appendix H). Although no specific sources of chlorinated benzenes have been documented in the SW Hanford CSO/SD (162) basin, because of the presence of heavy industrial activity in the basin that might entail the use of solvents, it is likely that there are numerous sources. Facilities that currently operate in the basin include a scrap metal dealer, a metal finisher, and several bulk petroleum storage facilities.

The highest PCB concentration observed during the drain sediment sampling effort (341,000 ug/kg) was found in the sediment from the Hanford CSO/SD (162). However, results from analytical replicates of this sediment varied from 28,800 to 341,000 ug/kg (mean=185,100 ug/kg). Several potential sources of PCBs have been identified in the basin, including a scrap metal recycler that reportedly handled transformers (Ryan, C., 6 July 1987, personal communication), and an oil recycler that collected oil from facilities in the area and drained oil from these transformers at various

locations on Harbor Island (Sweet-Edwards & Associates and Harper-Owes 1985).

1-Methylphenanthrene, another PAH, is commonly found in used crankcase oil (Peake and Parker 1980). The ratio of methylphenanthrene (MP) to phenanthrene (P) in sediment samples has been used to distinguish sources of combustion-related fossil fuel by-products from sources of noncombusted fuel by-products. Values of MP/P range from 2 to greater than 6 in noncombusted fuels, but are generally less than 1 in burned PAH mixtures (Prah1 and Carpenter 1983). The MP/P ratio in the sediments from the SW Hanford CSO/SD (162) is 0.43, which suggests that contamination in the drain sediments is probably related to sources of combusted fuel.

4.3.6 West Waterway

Sediment samples were collected from seven CSOs and city storm drains that discharge into the West Waterway (Figure 4-17).

Metals--

The results from the metals analyses of these drain sediments are summarized in Figure 4-18. The problem metals identified in the drain sediments included chromium, nickel, lead, and antimony. Chromium, nickel, and antimony were identified based on exceedances of the 90th percentile concentration, and lead was identified based on exceedance of the HAET value. The following metals have been identified as problem chemicals in the drains discharging into the West Waterway:

- SW Spokane CSO/SD (102) - chromium and nickel
- 16th Ave CSO/SD (104) - lead
- SW Florida CSO/SD (106) - lead
- SW Lander CSO/SD (105) - antimony and lead.

- LEGEND**
- TETRA TECH- THIS STUDY
 - ▲ METRO (1987)
 - GAMRONIA ET AL (1986)
 - ROMBERG ET AL (1984)
 - ▼ STÖBER AND CHEW (1984)
 - ◆ U.S. EPA (1982-1983)
 - MALINS ET AL (1980-1982)
 - TETRA TECH SOURCE SAMPLING STATION
 - ▲ METRO SOURCE SAMPLING STATION
 - SOURCE (INCLUDES STORM DRAINS AND CSOs) DISCHARGE LOCATION

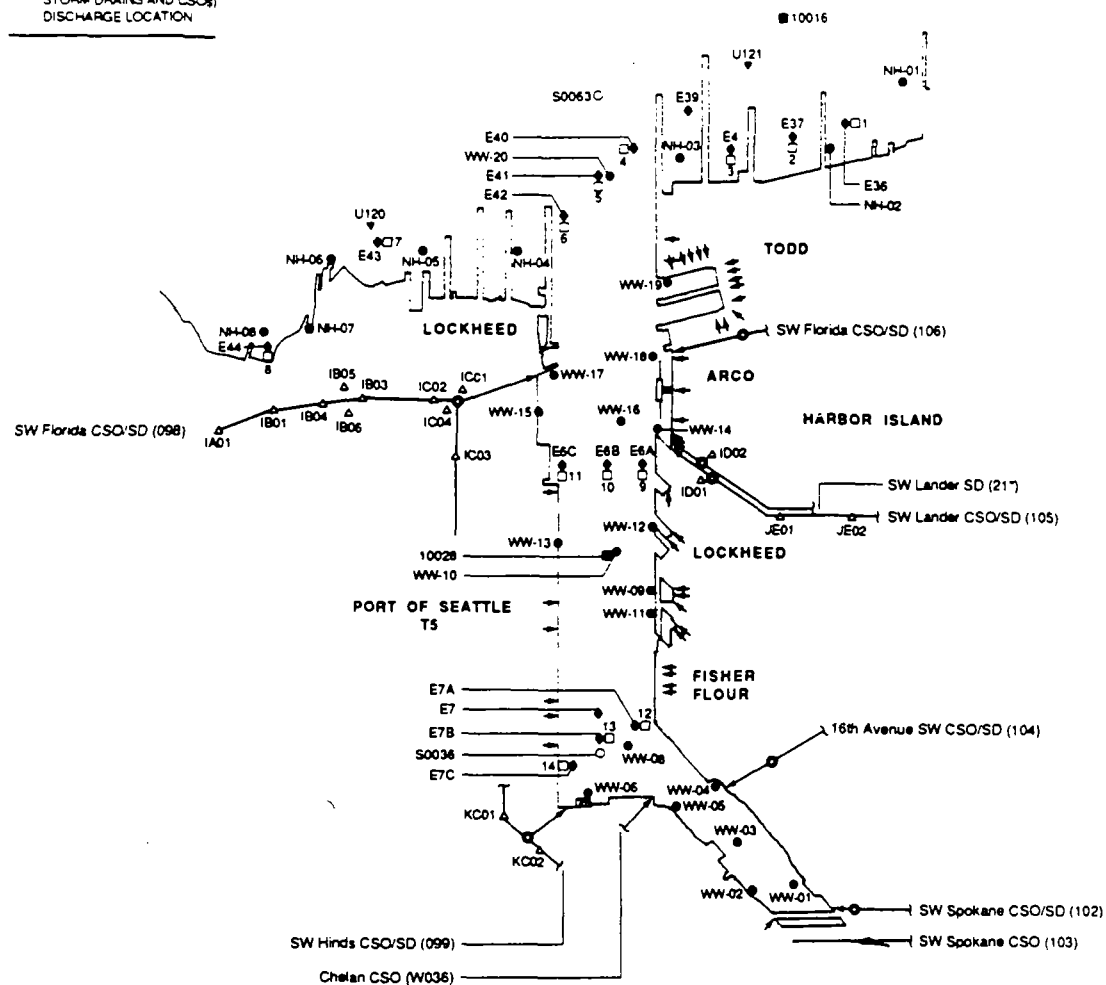


Figure 4-17. Locations of offshore and drain sampling stations, CSOs, and storm drains in the West Waterway study area.

CONCENTRATION (mg/kg dry weight)

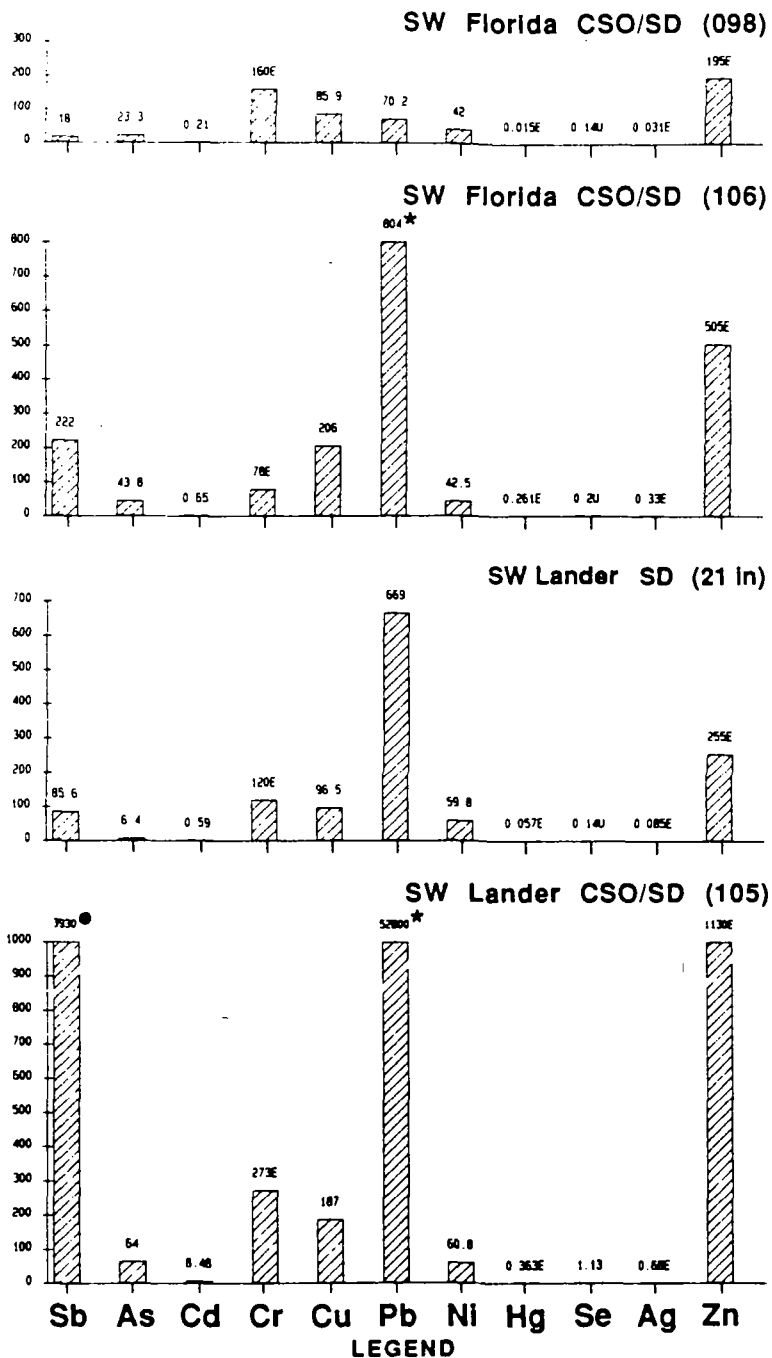
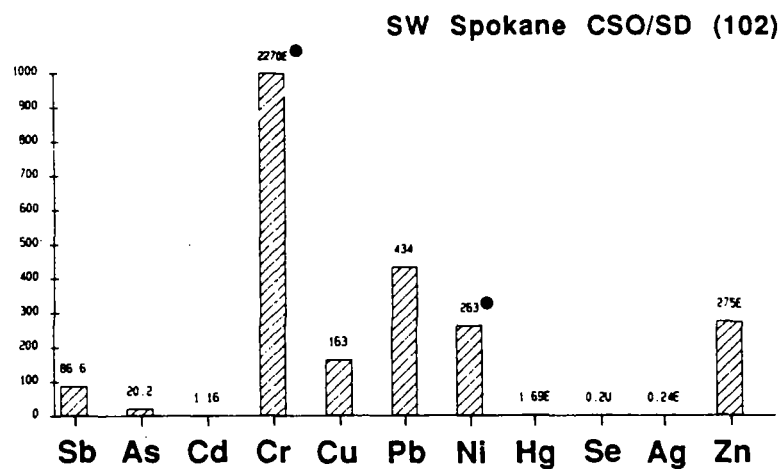
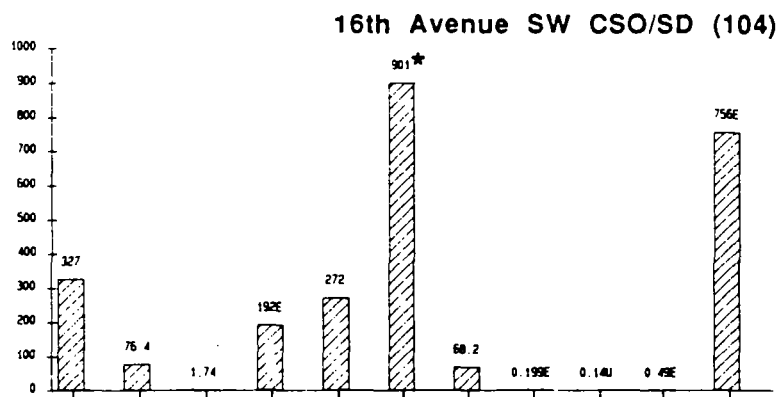
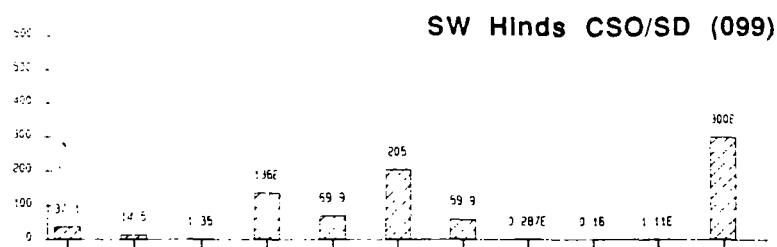


Figure 4-18. Concentrations of metals in sediments collected from drains discharging into the West Waterway study area.

CONCENTRATION (mg/kg dry weight)



LEGEND

★ EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-18. (Continued).

The SW Spokane CSO/SD (102) was the only drain in the West Waterway that exceeded the 90th percentile concentration for chromium (E797 mg/kg). The chromium concentration in SW Spokane CSO/SD (102) sediments (2,270 mg/kg) was the highest concentration observed in the study. In addition, chromium accounted for 65 percent of the total metals (sum of antimony, arsenic, chromium, copper, cadmium, lead, mercury, nickel, zinc, and antimony) observed in the sample. Uses of chromium are presented in Appendix H.

Two potential chromium sources in the SW Spokane CSO/SD (102) basin have been investigated by Metro and Ecology. A machine parts manufacturer (Meltec) discharges effluent from a quench tank (used to cool cast parts) into the SW Spokane CSO/SD (102) (Hubbard, T., 13 August 1984, personal communication). However, chromium was undetected in samples of the quench tank effluent collected by Metro on 7 November 1984 (Sample, T., 23 October 1987, personal communication). The second facility, a roofing company (Mono Roofing), mixes roofing compounds and maintains equipment onsite. Surface runoff from the site and wastewater from mixing operations enter the SW Spokane CSO/SD (102) system (Cargill, D., 20 October 1987, personal communication). Samples collected by Metro (21 June 1985) and Ecology (13 August 1987) indicate that this facility is a source of chromium. Water samples collected from site runoff and catch basins in the vicinity of the facility contained chromium at concentrations of 110-4,060 ug/L (Cargill, D., 20 October 1987, personal communication; and Sample, T., 23 October 1987, personal communication). Because loading information is unavailable for this source, it is not known whether discharges from the roofing company constitute a major source of chromium in the SW Spokane CSO/SD sediment.

Sediment from the SW Spokane CSO/SD (102) also contained nickel at concentrations exceeding the 90th percentile concentration (223 mg/kg) (see Figure 4-18). Nickel comprises 0.009 percent of the earth's crust (Kirk-Othmer 1985). The average concentration of nickel reported for U.S. soils is 19 mg/kg, and ranges from less than 5 mg/kg to 200 mg/kg (Kabata-Pendias and Pendias 1985). The nickel concentration measured in sediments from the SW Spokane CSO/SD (102) (263 mg/kg) exceeds the normal range for soils, and suggests one or more anthropogenic sources of nickel in the basin. Nickel alloys are commonly used to enhance the mechanical properties

of materials that are used in food processing equipment, chemical containers, and in plumbing and electromagnetic parts (see Appendix H). In addition, nickel is used in the production of catalysts, metal plating, nickel-cadmium batteries, and in the ceramics industry. There are no known sources of nickel in the SW Spokane CSO/SD basin (102). Nickel was undetected in water samples collected from the two facilities described above (roofing company and machine parts manufacturer) (Cargill, D., 20 October 1987, personal communication; and Sample, T., 23 October 1987, personal communication).

The HAET for lead (700 mg/kg) was exceeded in the sediments from the SW Lander CSO/SD (105), 16th Ave. SW CSO/SD (104), and the SW Florida SD (36 in) (see Figure 4-18). However, the lead concentration measured in the SW Lander CSO/SD (105) (52,800 mg/kg) was by far the highest concentration reported during the source sampling investigation, exceeding the concentrations measured in other drains in the project area by 1-3 orders of magnitude. In addition, lead constituted over 90 percent of the total metals (sum of antimony, arsenic, cadmium, copper, chromium, lead, mercury, nickel, silver, and zinc) in the Lander sediment sample.

The lead contamination in the Lander CSO/SD (105) has been attributed to emissions from a secondary lead smelter that operated in the Lander basin between 1937 and 1984 (Hubbard and Sample 1988). Metro sampled the Lander CSO/SD (105) in 1984 and found sediments in the drain contaminated with lead at concentrations ranging from 247,000 to 358,000 mg/kg (25-36 percent lead, dry weight; Hubbard and Sample 1988). Metro traced the lead contamination to the secondary lead smelter (Hubbard and Sample 1988).

Lead concentrations as high as 180,000 mg/kg were reported in soil samples collected near the smelter property by the Puget Sound Air Pollution Control Agency (PSAPCA) (PSAPCA 1980). The elevated concentrations of airborne lead were due primarily to emissions from the secondary lead smelter and the re-entrainment of road dust, which had been contaminated with lead due to past emissions (PSAPCA 1983a). Lead that has accumulated in surface soils is transported by stormwater runoff to the West Waterway via storm drains. Although contaminated sediments were removed from the Lander CSO/SD (105) by the City of Seattle in 1984, and some parking lots in the area

were paved in 1983 to reduce fugitive dust emissions (Hubbard and Sample 1988), the results of this study indicate that residual contamination from the lead smelter is an ongoing source of lead in the Lander CSO/SD (105).

Metro found 150,000 mg/kg lead in the Lander CSO/SD (105) in a sediment sample when they resampled the drain on 2 September 1986 (Sample, T., 23 October 1987, personal communication). In addition, Metro and the City of Seattle collected soil samples from three unpaved parking lots located along 16th Ave. SW on Harbor Island (northeast corner of 16th Ave. SW and SW Lander St., northeast corner of 16th Ave. SW and SW Hanford St., and southeast corner of 16th Ave. SW and SW Florida St.) and found lead in concentrations of 553-1,546 mg/kg (Spencer, J., 27 May 1988, personal communication). The three samples were composites of surface soil scraped from four to five locations in each parking lot. Only the soil sample from the lot at SW Florida St. (1,546 mg/kg) exceeded the HAET for lead (300 mg/kg). The concentrations of lead measured in the three parking lots were about 10 times lower than the lead concentrations found in the drain sediments after the 1984 cleaning project (15,000-52,800 mg/kg lead). This difference suggests that the parking lots are not the major ongoing source of lead in the SW Lander CSO/SD (105).

Samples for the Elliott Bay Action Program were collected approximately 1 yr after the Lander CSO/SD (105) cleaning operations were completed. Sediment samples were collected from the manhole located midway between 16th Ave. SW and the drain outfall. This is the station that exhibited the highest concentration of lead (370,000 mg/kg) during Metro's sediment sampling program in 1984. The results indicate that there is an ongoing source of lead in the Lander CSO/SD (105) drainage basin. Lead concentrations (52,800 mg/kg), measured during the Elliott Bay Action Program, although lower than Metro's original results (370,000 mg/kg), continue to exceed the HAET for lead (1,600 mg/kg). Results were approximately 100 times greater than the concentrations reported in normal urban street dust (520 mg/kg; Galvin and Moore 1982).

Although lead contamination remains a problem in the Lander CSO/SD (105) drainage system, Curl et al. (1987) reported a decrease of 1 order of

magnitude or more in dissolved lead concentrations in water samples collected off the head of the West Waterway in 1985 and 1986 relative to samples collected in 1981. Because their analyses indicated that the decrease in lead concentrations was due to decreased inputs of lead from sources downstream of the turning basin, they attributed this decrease to the pollution abatement programs conducted by local, state, and federal agencies.

HAET exceedances for lead also occurred in the 16th Ave. SW CSO/SD (104) and SW Florida CSO/SD (106) (see Figure 4-18). The drainage basins from these two drains are located immediately adjacent to the Lander CSO/SD (105) basin. Therefore, it is likely that these basins have also been affected by historic smelter emissions.

Sediments from the SW Lander CSO/SD (105) also contained antimony (3,931 mg/kg) at concentrations exceeding the 90th percentile concentration of 775 mg/kg (see Figure 4-18). Antimony is used in abrasives, pigments, flameproofing compounds, plasticizers, and catalysts in organic synthesis. Additionally, antimony is used in the manufacture of paints, lacquers, glass, pottery, enamel, glazes, and pharmaceuticals (Kirk-Othmer 1985). Antimony is often present in lead ores and is recovered as a by-product during the lead smelting process (Hawley 1981). In addition, antimony is commonly used in metal alloys. Because scrap lead storage batteries were used as the primary source of lead at the secondary lead smelter on Harbor Island, this facility was the likely source of antimony in the Lander CSO/SD (105) sediments.

No metals exceeded the HAET or 90th percentile concentrations in the SW Florida CSO/SD (098) or SW Lander SD (21 in) sediment samples (see Figure 4-18). However, sediments were removed from the SW Florida CSO/SD (098) about 1 yr prior to the Elliott Bay Action Program sampling effort as part of cleaning operations conducted by the City of Seattle. Prior to the cleaning operations, sediments in the SW Florida CSO/SD (098) were contaminated (i.e., exceeded HAET) with arsenic and copper. Contamination has been attributed to discharges from Wyckoff's West Seattle wood treating plant (Hubbard and Sample 1988). Metro resampled the SW Florida CSO/SD (098) in

1986 and found that sediment from a catch basin further upstream in the system (on Wyckoffs' property) was again contaminated with chemicals (i.e., pentachlorophenol, HPAH, and LPAH) used in the wood treatment process (Sample, T., 27 March 1987, personal communication). Although metal concentrations were not reported, it is likely that arsenic and copper, which are also used in the wood treatment process, are a continuing problem in the SW Florida CSO/SD (098) basin. Metro has reported that stormwater runoff from the plant area is responsible for the contamination in the catch basin sediments (Sample, T., 27 March 1987, personal communication).

Organic Compounds--

Selected organic compounds measured in sediments from the drains discharging into the West Waterway are summarized in Figure 4-19. PAH, p,p'-DDT, methylphenols, total xylenes, and benzoic acid have been identified as problem chemicals in the West Waterway drains:

- SW Hinds CSO/SD (099) - 4-methylphenol
- SW Spokane CSO/SD (102) - benzoic acid
- 16th Ave. SW CSO/SD (104) - 2-methylphenol, 1-methylphenanthrene, and p,p'-DDT
- SW Lander CSO/SD (105) - total xylenes
- SW Florida CSO/SD (106) - benzoic acid.

Sediments from the SW Florida CSO/SD (098) and SW Lander SD (21 in) did not exceed an HAET or 90th percentile concentration for any organic compounds. However, as was explained above, the SW Florida CSO/SD (098) has a long history of PAH, PCB, and pentachlorophenol contamination, which has been traced to a wood treatment facility (Wyckoff) and a scrap yard operating in the basin (Hubbard and Sample 1988). Metro collected sediments from the SW Florida CSO/SD (098) system in April and October 1984 and found that the sediments in the drain were contaminated with PAH, arsenic, copper, and PCBs

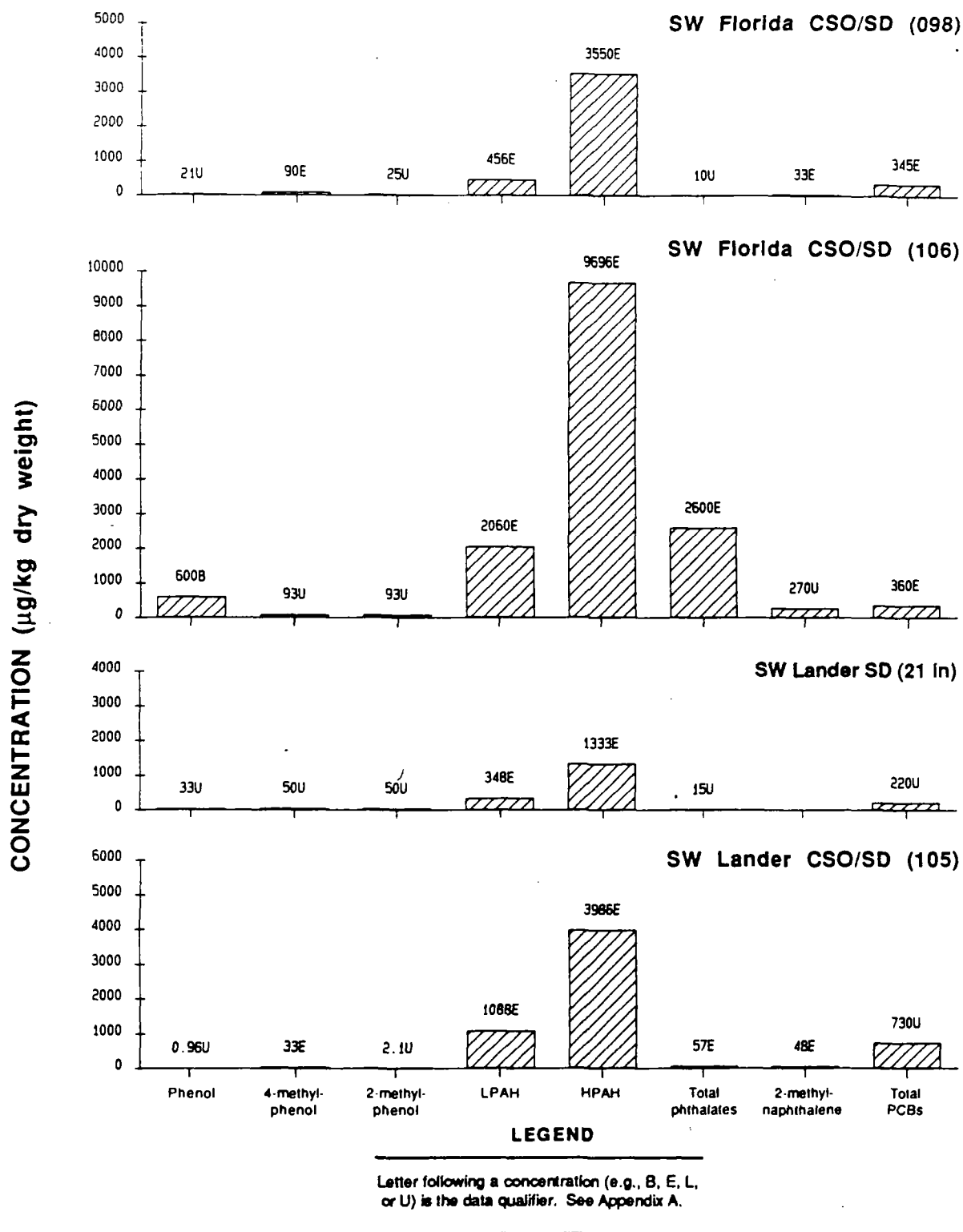
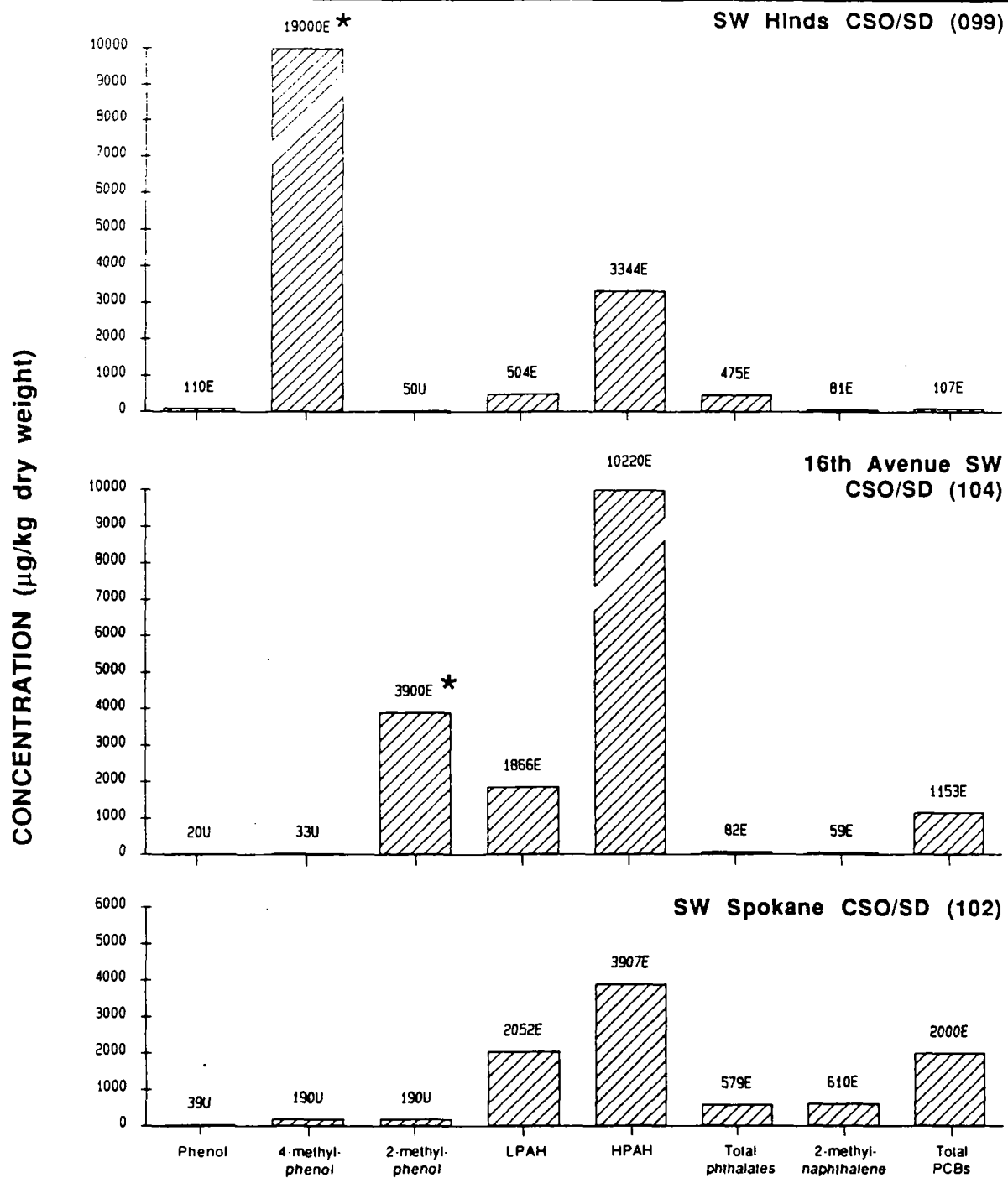


Figure 4-19. Concentrations of selected organic compounds in sediments collected from drains discharging into the West Waterway study area.



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., B, E, L, or U) is the data qualifier. See Appendix A.

Figure 4-19. (Continued).

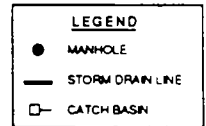
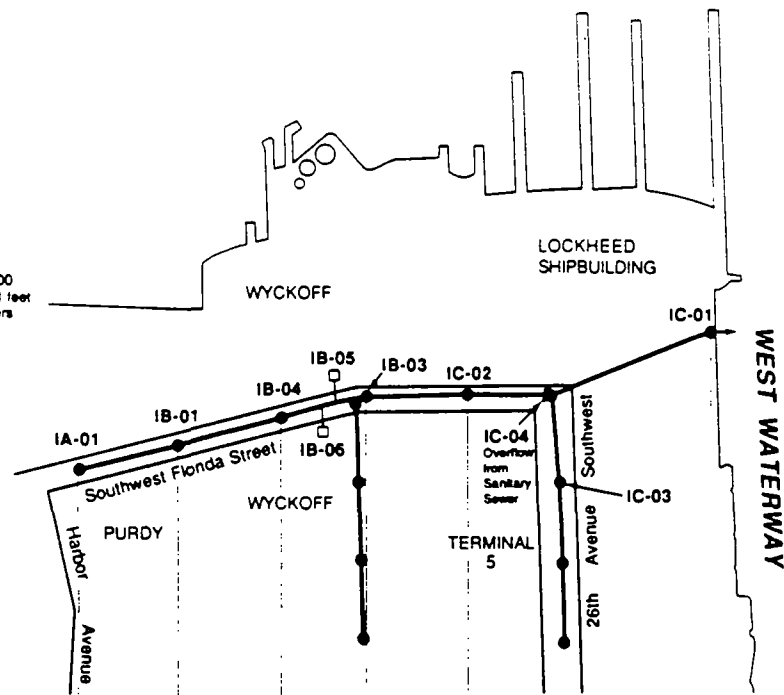
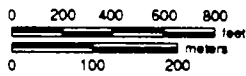
(Hubbard and Sample 1988). Contaminant concentrations profiles for the SW Florida CSO/SD are summarized in Figure 4-20. Based on their investigation, Metro determined that the metals, PAH, and pentachlorophenol were associated with discharges from the Wyckoff's West Seattle facility in the drainage basin, and that the PCBs were associated with a scrap yard (Purdy) that had recycled old transformers containing PCBs (Hubbard and Sample 1988).

Metro's results are consistent with evidence obtained by U.S. EPA during a 1983 investigation of the wood treatment facility. U.S. EPA inspectors found that the wood treatment plant had illegally discharged hazardous wastes from their facility into a catch basin connected to the SW Florida CSO/SD (McClary, D., 6 November 1987, personal communication). As a result, the company was convicted on criminal charges, fined, placed on probation, and was required to cease illegal discharges to the storm drain system. The exact location of the PCB contamination at the scrap yard has not yet been determined due to discrepancies in the data from soil sampling conducted at the property (Cargill, D., 25 February 1988, personal communication). However, the scrap yard has stopped handling PCB transformers (Hubbard and Sample 1988).

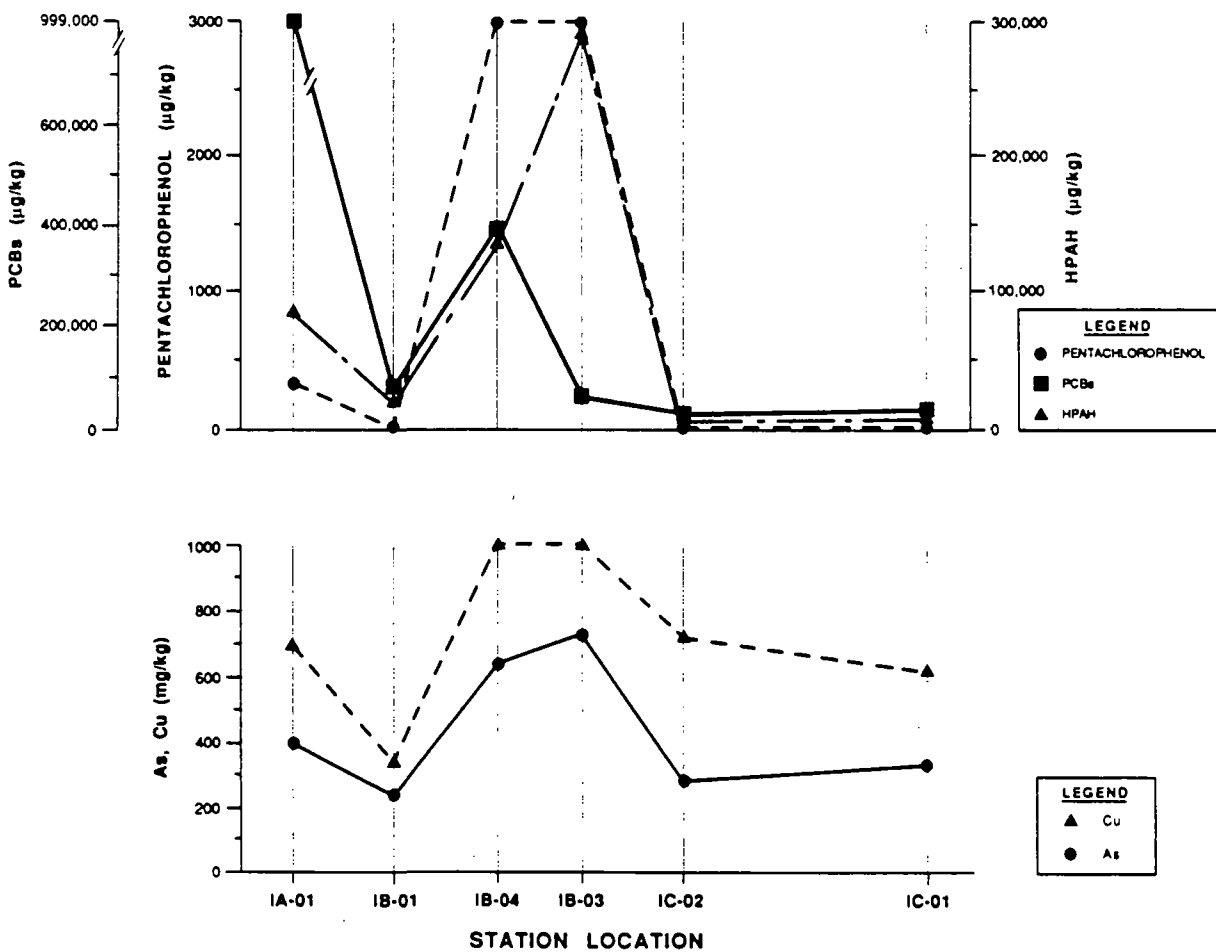
In August 1985, the City of Seattle removed the contaminated sediments from the SW Florida CSO/SD (098). Approximately 30 yd³ of contaminated sediments were removed from the trunk line under SW Florida St. and from catch basins connected to the drain line (Schwartz, L., 1 August 1985, personal communication).

During the Elliott Bay Action Program sampling effort, a single sediment sample was collected from the farthest downstream manhole on the SW Florida CSO/SD (098) line (see Figure 4-17). The sampling was conducted approximately one month after the cleaning operations had been completed. Contaminant concentrations measured in the Elliott Bay Action Program sample were consistently lower than the concentrations reported in the Metro samples. There were no problem chemicals (i.e., no chemicals exceeded an HAET or a 90th percentile concentration) identified in the SW Florida CSO/SD (098) sample. Concentrations of the contaminants found by Metro (i.e.,

PLAN VIEW



CONTAMINANT CONCENTRATION PROFILES



Reference: Sample T, 23 October 1987, personal communication

Figure 4-20. Contaminant concentration profiles for the SW Florida Street CSO/SD.

arsenic, copper, HPAH, pentachlorophenol, and PCBs) were 2-100 times lower in the samples collected after the drain was cleaned:

<u>Chemical</u>	<u>Metro (10/84)</u>	<u>Elliott Bay Action Program (9/85)</u>	<u>HAET</u>
Pentachlorophenol (ug/kg)	U-7,800	U160	--
HPAH (ug/kg)	3,220-293,200	E3,550	38,000
LPAH (ug/kg)		E456	6,100
Arsenic (mg/kg)	240-730	23.3	700
Copper (mg/kg)	340-1,000	85.9	800
PCBs (ug/kg)	490-810,000	E345	2,500

Metro resampled one of the catch basins on the wood treatment plant's property in March 1986 and found that the sediments were again contaminated with HPAH (106,700 ug/kg), LPAH (22,300 ug/kg), and pentachlorophenol (1,740 ug/kg) (Sample, T., 27 March 1987, personal communication). The contamination was believed to be associated with stormwater runoff from the property.

Benzoic acid has been identified as a problem chemical in the SW Spokane CSO/SD (102) (3,400 ug/kg) and the SW Florida CSO/SD (106) (2,500 ug/kg). Benzoic acid was undetected in the other five drains discharging to the West Waterway at analytical detection limits of 16-200 ug/kg (HAET=650 ug/kg). Benzoic acid and its salts and esters are used in many products including medicinals, veterinary medicines, food and industrial preservatives, cosmetics, resin preparations, plasticizers, dyestuffs, synthetic fibers, tobacco curing, and as chemical intermediates (Kirk-Othmer 1985; also see Appendix H). No specific sources of benzoic acid have been documented in the SW Florida CSO/SD (106) and the SW Spokane CSO/SD (102) basins. There are no similarities in the types of industries operating in the two basins. The SW Florida CSO/SD (106) basin is occupied exclusively by petroleum-related facilities and the SW Spokane CSO/SD (102) basin is occupied by a scrap metal recycler, a roofing company, a paint manufacturer, and a hardware store. Therefore, the contamination in these two basins appears to be from unrelated sources.

A waste pond located on the Seattle Iron and Metals property that was utilized by the previous tenant, Weyerhaeuser, may be a source of benzoic acid contamination in the SW Spokane CSO/SD (102) basin. Ecology and Environment (1985) reported that Weyerhaeuser disposed of laboratory wastes in a pond onsite. Seattle Iron and Metals purchased the Weyerhaeuser property in 1978 and paved over the waste pond in 1980 with 4 in of asphalt (Ecology and Environment 1985). Weyerhaeuser conducted research at this facility between 1962 and 1978. Research activities included testing the adhesive characteristics of wood resins and glues for use on different types of wood. Because benzoic acid is used in resin preparations, it is possible that wastes from these operations contained benzoic acid. In addition, Ecology reported that as recently as 1985, pipes from the former Weyerhaeuser and Pacific Resins and Chemicals terminated at a sump, which at one time apparently discharged to the waste pond (Dorigan, L., 30 June 1987, personal communication). Because the former Weyerhaeuser research facility (currently occupied by the Harbor Island Business Center) has recently been renovated, and the drains were plugged, this is not considered an ongoing source. However, the pond may be contributing to groundwater contamination.

The concentrations of methylphenols exceeded HAET in the sediments from the SW Hinds CSO/SD (099) (4-methylphenol) and 16th Ave. SW CSO/SD (104) (2-methylphenol) (see Figure 4-19). The concentration of 2-methylphenol in the 16th Ave. CSO/SD (104) sediments (3,900 ug/kg) was the highest concentration measured in the drain sampling program. 2-Methylphenol is frequently found in the effluent from pulp mills (Tetra Tech 1985a). Uses of both 2-methylphenol and 4-methylphenol are provided in Appendix H.

There are no documented sources of these compounds in either basin. The SW Hinds CSO/SD (099) serves approximately 1,400 ac in West Seattle. A large portion of the area constitutes the upper Longfellow Creek drainage basin (see Map 3 in Map Appendix). Under low flow conditions, flow from the upper Longfellow Creek basin is diverted to the SW Hinds CSO/SD (099) at SW Andover St. and discharges to the West Waterway. No potential sources of 4-methylphenol have yet been identified in this basin. The only potential contaminant source that has been identified in the SW Hinds CSO/SD (099) basin is a steel mill, which has no apparent association with 4-methylphenol.

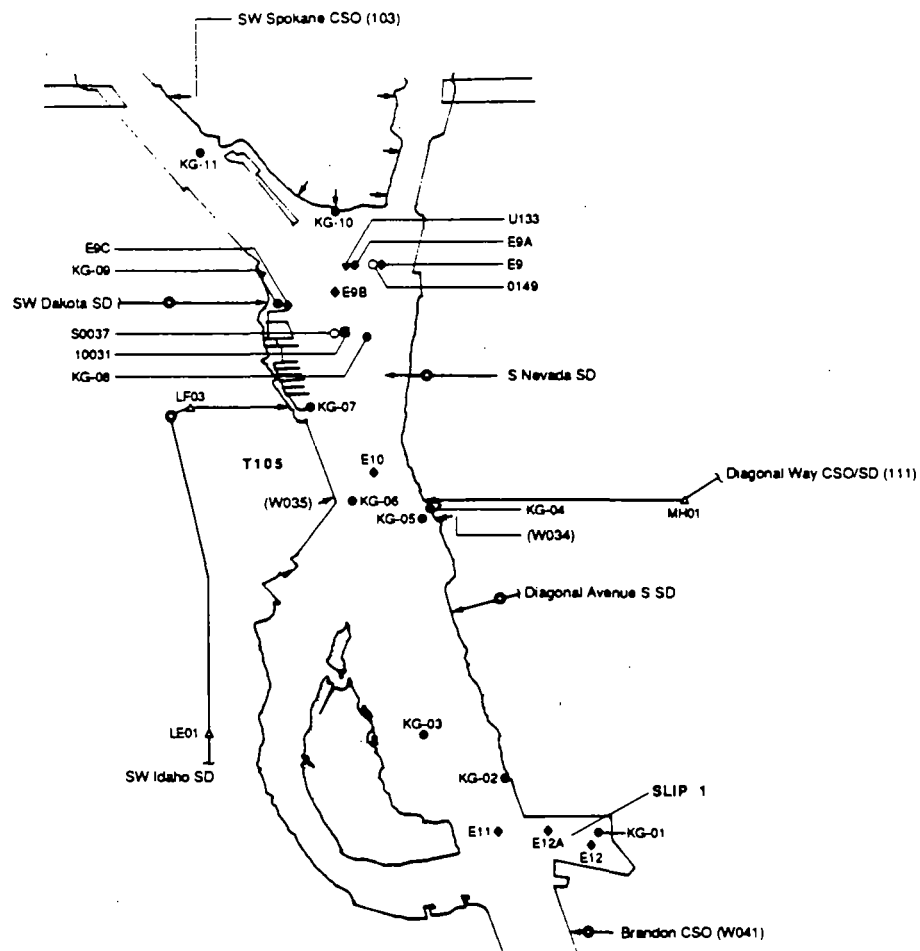
The 16th Ave. SW CSO/SD (104) basin is currently occupied by an engineering and design firm, a flour and bulgar mill, and a wholesale distributor of valves and fittings. There are no known sources of alkylated phenols in this basin.

Other chemicals that exceeded HAET in the 16th Ave. SW CSO/SD (104) include 1-methylphenanthrene (470 ug/kg) and p,p'-DDT (21 ug/kg). 1-Methylphenanthrene is a PAH; uses of PAH are presented in Appendix H. The MP/P ratio of 0.54 in the drain sediments suggests that the 1-methylphenanthrene contamination may be related to combusted fuel materials. p,p'-DDT contamination in the drain is probably caused by past usage, because the use of p,p'-DDT is currently restricted (Kirk-Othmer 1985).

The total xylenes concentration measured in the Lander CSO/SD (105) sediments (187 ug/kg) was the highest concentration observed in all of the drains sampled during the study and exceeded the HAET (120 ug/kg) concentration. Xylenes were detected in all 20 samples of the drain sediments. The concentration in the Lander CSO/SD (105) was 1.1-160 times greater than the concentrations measured in the other drains in the study. The majority of xylenes are used in gasoline production (Kirk-Othmer 1985; see also Appendix H). Xylenes are also used as solvents in paints, lacquers, varnishes, inks, dyes, adhesives, cements, and cleaning fluids. In addition, xylenes are used as feedstock for compounds used in the manufacture of plastic materials and synthetic fabrics, quartz crystal oscillators, hydrogen peroxide, and perfumes (Kirk-Othmer 1985). The most likely sources of xylenes in the basin are gasoline spills and surface runoff. The Lander CSO/SD (105) basin is currently occupied by a bulk petroleum storage facility (Texaco), several metals-related industries, and a rendering plant.

4.3.7 Kellogg Island

Sediment samples were collected from all four of the city storm drains (SW Dakota SD, SW Idaho SD, Diagonal Ave. S. SD, and S. Nevada SD) and one CSO/SD [Diagonal Way CSO/SD (111)] that discharge into the Kellogg Island study area (Figure 4-21). The overflows on the Metro siphon (W034 and W055)



LEGEND

- TETRA TECH (THIS STUDY)
- ▲ METRO (1987)
- GAMPNIA ET AL. (1986)
- ROMBERG ET AL. (1984)
- ▼ STÖBER AND CHEW (1984)
- ◆ U.S. EPA (1982, 1983)
- MALINS ET AL. (1980, 1982)
- TETRA TECH SOURCE SAMPLING STATION
- ▲ METRO SOURCE SAMPLING STATION
- SOURCE (INCLUDES STORM DRAINS AND CSOs) DISCHARGE LOCATION



Figure 4-21. Locations of offshore and drain sampling stations, CSOs, and storm drains in the Kellogg Island study area.

were not sampled during the sampling program, because they function only as emergency overflows in the event of a siphon failure.

Metals--

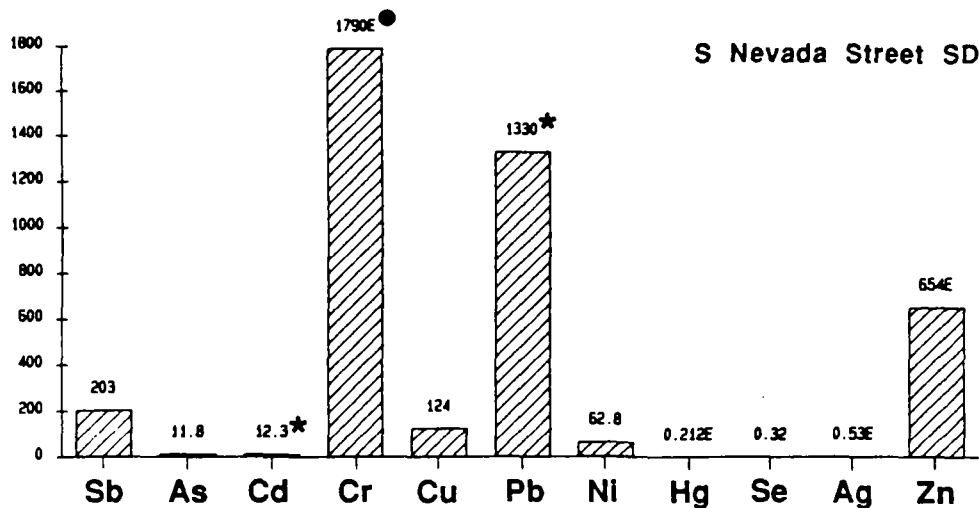
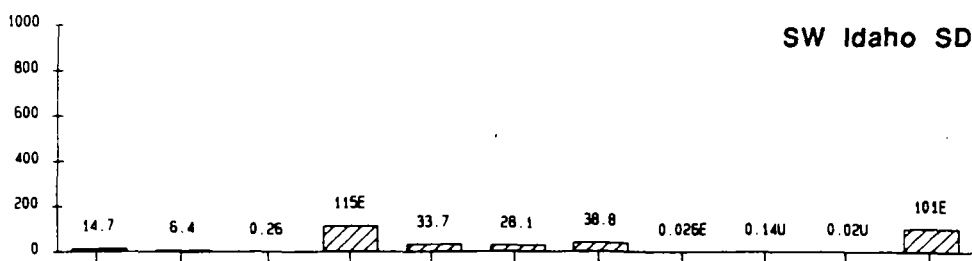
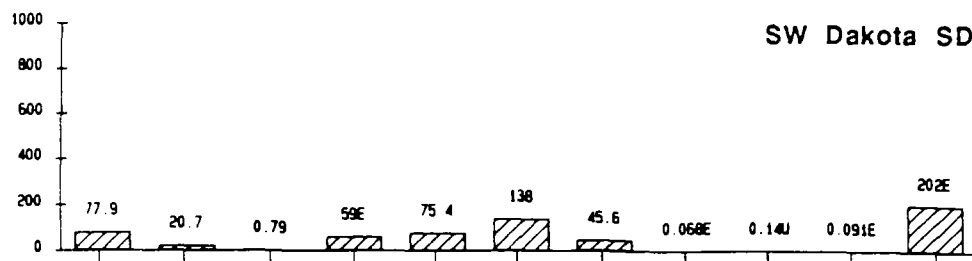
The results from the metals analyses of these drains are summarized in Figure 4-22. HAETs for cadmium and lead (9.6 and 700 mg/kg, respectively), and 90th percentile concentrations for chromium (797 mg/kg) were exceeded in the sediments collected from the S. Nevada SD. The concentrations of metals did not exceed HAET or the 90th percentile concentrations in any of the other drains sampled in this study area.

The relative distribution of metals in the sediments collected from the SW Dakota SD, SW Idaho SD, Diagonal Way SD (111), and the Diagonal Ave. S. SD is summarized in Table 4-8. With the exception of chromium in the SW Idaho SD, the relative distribution of metals in each of these four drains was similar to the relative distribution of metals reported in urban street dust (Galvin and Moore 1982). Therefore, it is likely that the metals found in the sediments from these drains were contributed from nonpoint sources such as urban runoff.

In general, the relative distribution of metals in the S. Nevada SD was similar to the relative distribution of metals reported in street dust (see Table 4-8). However, the concentration of chromium (1,790 mg/kg) exceeded the 90th percentile concentration (797 mg/kg) in the sediments. The relative abundance of chromium (43 percent) in the S. Nevada sediments was greater than the range reported in street dust (2-24 percent), and was also greater than its relative abundance in the other drains in the segment (10-34 percent). In addition, the concentration of chromium in the drain sediments (1,790 mg/kg) was 1-2 orders of magnitude greater than the concentrations in street dust (20-230 mg/kg) (Galvin and Moore 1982). Consequently, it appears that there may have been sources of chromium other than street dust in the S. Nevada SD basin.

Cadmium and lead also exceeded the HAET in sediments collected from the S. Nevada SD. The relative abundances of these two metals in the drain

CONCENTRATION (mg/kg dry weight)



LEGEND

* EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-22. Concentrations of metals in sediments collected from drains discharging into the Kellogg Island study area.

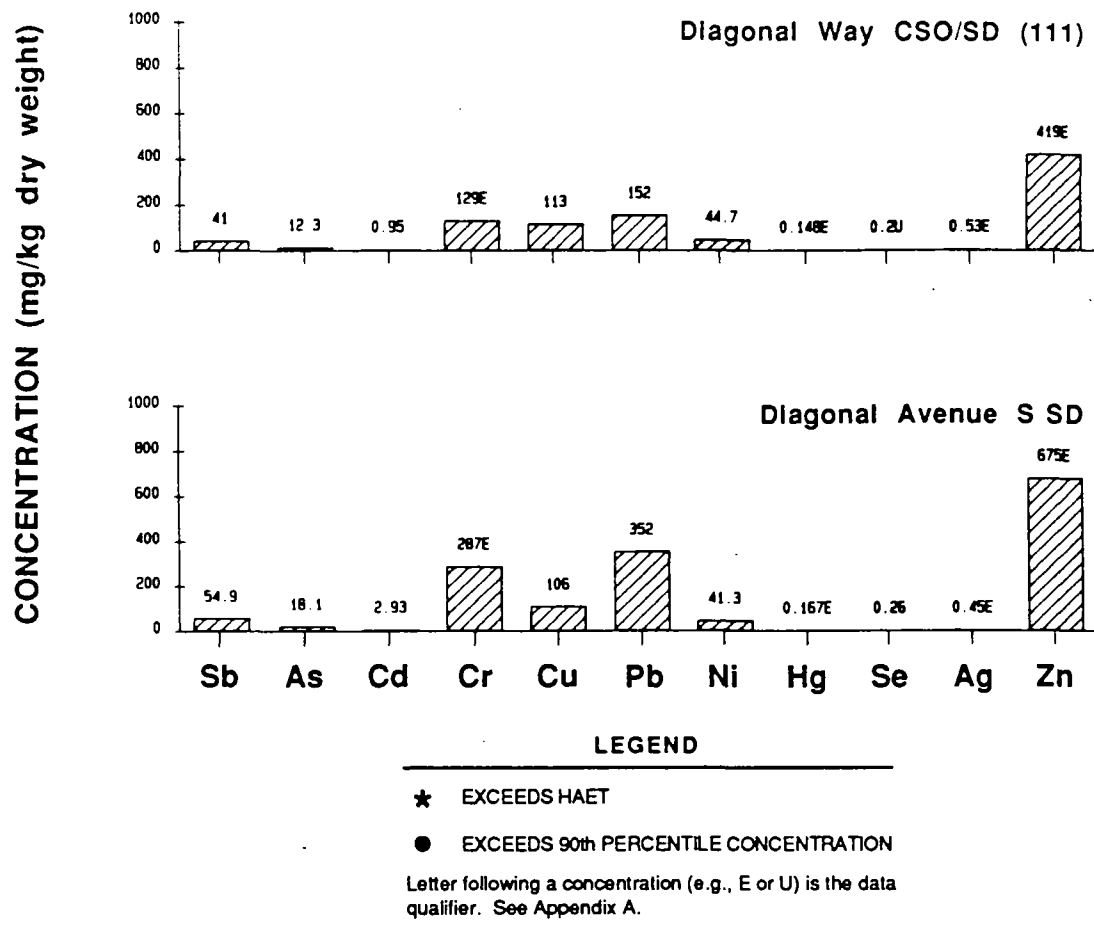


Figure 4-22. (Continued).

TABLE 4-8. RELATIVE PERCENT DISTRIBUTION OF METALS
IN SEDIMENTS FROM DRAINS DISCHARGING INTO THE KELLOGG ISLAND STUDY AREA

Metals	SW Dakota SD	SW Idaho SD	Diagonal Way CSO/SD (111)	Diagonal SD	Nevada SD	Street Dust ^a	Street Dust ^b
Antimony	13	4	4	4	5	<1	<1
Arsenic	3	2	1	18.1	<1	1-5	1-5
Cadmium	<1	<1	<1	<1	<1	<1	<1
Chromium	10	34	14	19	43	2-15	2-24
Copper	12	10	12	7	3	4-12	3-29
Lead	22	8	17	23	32	30-64	10-77
Mercury	<1	<1	<1	<1	<1	<1	<1
Nickel	7	11	5	3	2	2-4	2-5
Silver	<1	<1	<1	<1	<1	<1	<1
Zinc	33	30	46	44	16	14-54	17-47
Total metals (mg/kg)	620 ^c	340 ^c	913 ^c	0.540 ^c	4,200 ^c	680-1,800 ^d	530-1,100 ^d

^a Commercial and industrial sites (Galvin and Moore 1982).

^b Residential land use.

^c Values reported as dry-weight concentrations.

^d Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

sediments were within the range reported for urban street dust (see Table 4-8). The concentration of lead (1,330 mg/kg) was nearly within the range of concentrations reported in urban street dust (90-1,300 mg/kg; Galvin and Moore 1982). However, the concentration of lead in the S. Nevada sediments was 1-2 orders of magnitude greater than the lead concentrations in the other drains in the segment. Similarly, the cadmium concentration in S. Nevada SD sediments was 4-10 times greater than the concentrations in the other drains and exceeded the concentrations reported in urban street dust (0.6-2.0 mg/kg). Therefore, it is likely that there were one or more sources of these metals other than urban runoff in the S. Nevada SD basin.

There are no documented sources of cadmium, chromium, or lead in the Nevada SD basin. The drain is only 140 ft long and serves a 30-ac area. The majority of the basin is occupied by a large warehouse on Port of Seattle Terminal 106 property.

Organic Compounds--

Selected organic compounds in the drains discharging into the Kellogg Island study area are summarized in Figure 4-23. PAH, chlorinated benzenes, phthalates, and phenols were identified as problem chemicals in the drains:

- Diagonal Ave. S. SD - indeno(1,2,3-c,d)pyrene, total phthalates
- Diagonal Way CSO/SD (111) - 1,2-dichlorobenzene, 1,4-dichlorobenzene, total chlorinated benzenes, phenol, 4-methylphenol, dimethyl phthalate, and indeno(1,2,3-c,d)pyrene.

There were no organic compounds at concentrations exceeding HAET or 90th percentile concentrations in the SW Dakota SD or the SW Idaho SD.

PAH compounds were the most abundant organic contaminants in the drains in the Kellogg Island study area. The range of ratios of HPAH to LPAH was relatively constant (i.e., 2.5-2.9) in all drains except the Diagonal Ave. S. SD. The Diagonal Ave. S. SD contained a higher proportion

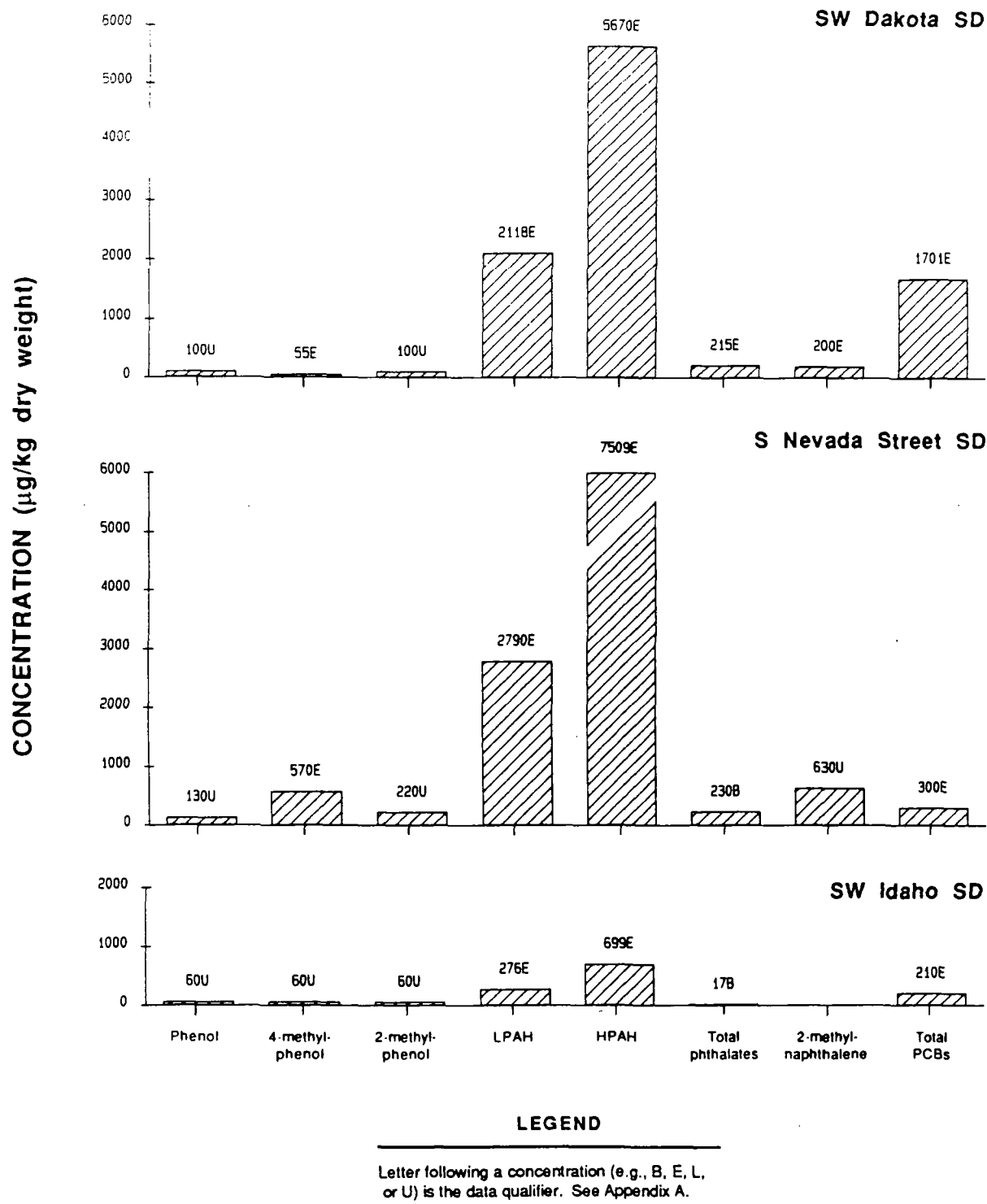
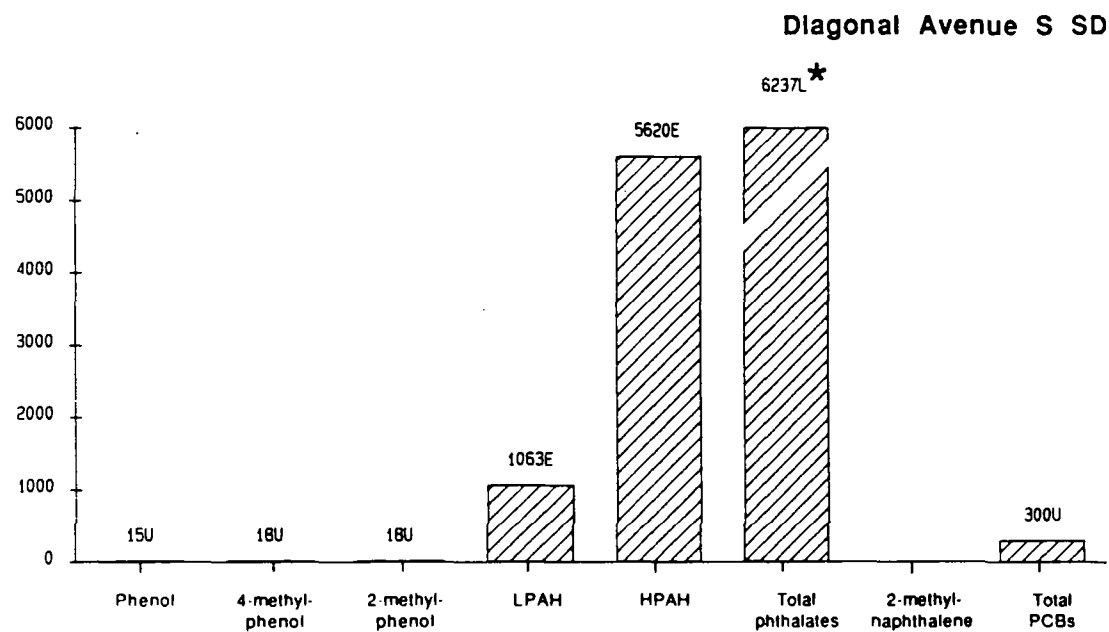
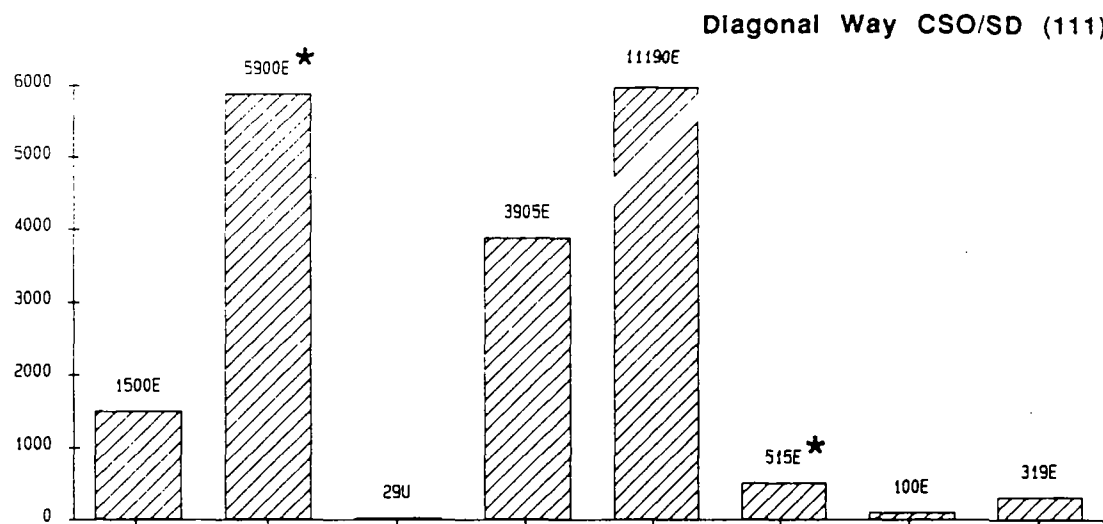


Figure 4-23. Concentrations of selected organic compounds in sediments collected from drains discharging into Kellogg Island study area.

CONCENTRATION ($\mu\text{g/kg}$ dry weight)



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., B, E, L, or U) is the data qualifier. See Appendix A.

Figure 4-23. (Continued).

of HPAH to LPAH (5.3). This difference suggests that there are different PAH sources for the Diagonal Ave. S. SD than for other drains in the Kellogg Island study area. The ratio of HPAH to LPAH has been used to indicate the type of PAH source contributing to the contamination. In general, HPAH are associated with combusted fossil fuel sources and LPAH are associated with uncombusted fuel sources (Prah1 and Carpenter 1983). Because sediment from the Diagonal Ave. S. SD contained more HPAH, there may have been a larger proportion of combustion-related sources in the basin than in other basins in the Kellogg Island study area.

Indeno(1,2,3-c,d)pyrene, an HPAH compound, was not found in samples of street dust collected by Galvin and Moore (1982). Indeno(1,2,3-c,d)pyrene has been identified as a component of coal and wood combustion products (Lee et al. 1977). The Diagonal Ave. S. SD serves a relatively small basin (12 ac) located north of Diagonal Ave. S. between E. Marginal Way S. and the Duwamish River. Most of the basin is paved and appears to be currently used for storage by the surrounding properties. Contamination in this drain may have been associated with historic rather than ongoing sources.

The Diagonal Way CSO/SD (111) serves a large basin (storm drain=1,030 ac, sanitary sewer=4,003 ac) (see Map 3 in Map Appendix). The basin is composed of residential, commercial, and industrial land uses. Because of the large drainage area served, there are probably multiple sources of indeno(1,2,3-c,d)pyrene in the basin. No specific sources have been documented. Potential sources have been identified based on information from Ecology, U.S. EPA, and Metro. These sources include a machine shop (Ecology 1987), a tank cleaning service, a utility storage area (U.S. EPA, 22 October 1987, personal communication), and the 6th Ave. S. landfill (Seattle-King County Public Health Department 1984).

Phthalates were identified as problem chemicals in the Diagonal Ave. S. SD (total phthalates) and Diagonal Way CSO/SD (111) (dimethyl phthalate) (see Figure 4-23). Phthalate contamination in the Diagonal Ave. S. SD consisted entirely of di-n-octyl phthalate. Because of their widespread use (see Appendix H), there may have been multiple sources of phthalates. The Diagonal Ave. S. SD basin is relatively small and appears to be used as

storage by nearby property owners. No specific sources of phthalates have been identified in the basin. Phthalate contamination in this drain may have been related to historical sources.

Part of the inactive 6th Ave. S. landfill lies within the Diagonal Way CSO/SD (111) basin. Decomposing garbage is a potential source of phthalates. The landfill operated for about 30 yr prior to about 1955 and accepted primarily municipal garbage and dredged materials from the Duwamish Waterway. There have been recent complaints of odor problems in the area. Leachate from the landfill is believed to have contaminated groundwater in the area (Seattle-King County Public Health Department 1984). Infiltration of contaminated groundwater is a potential pathway for contaminants to the Diagonal Way CSO/SD (111).

One specific source of phthalates has been identified in the Diagonal CSO/SD basin. In 1984, U.S. EPA inspectors observed Janco-United, a distributor of disinfectants and soaps, floor cleaners, and degreasing agents, discharging wastes from tank-cleaning operations into the Diagonal Way CSO/SD (111) system (Mann, C., 27 April 1988, personal communication). During the investigation, samples were collected from soil in the area around the facility and from a drain beneath the facility. Phthalates were found in the soil and drainage samples. Soil samples contained 11,000-95,000 ug/kg of bis(2-ethylhexyl)phthalate, 75,000-350,000 ug/kg of di-n-butyl phthalate, and 200-530 ug/kg of dimethyl phthalate. Drainage samples contained 200-15,000 ug/L of butyl benzyl phthalate and 85,000-9,400,000 ug/kg of di-n-butyl phthalate (Mann, C., 2 May 1988, personal communication). The samples also contained several volatile organic compounds (1,1,1-trichloroethane, benzene, chloroform, tetrachloroethene, toluene, acetone, and trichloroethene), PAH, benzyl alcohol, benzoic acid, and numerous tentatively identified compounds (e.g. methyl benzenes). Based on the results of U.S EPA's investigation, Janco-United was convicted of criminal charges, fined, and two of its principals were jailed (Mann, C., 27 April 1988, personal communication). Janco-United moved to a new location outside the Elliott Bay project area in December 1984.

The concentrations of chlorinated benzenes in the sediment from the Diagonal Way CSO/SD (111) (E34,260 ug/kg total chlorinated benzenes) were the highest concentrations measured in the sampling program. The major constituent was 1,4-dichlorobenzene (E34,000 ug/kg), with a much smaller amount of 1,2-dichlorobenzene (E260 ug/kg). Chlorinated benzenes have been used in the production of phenol, aniline, diphenyl oxide, and p,p'-DDT. Uses of chlorobenzene, 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene are presented in Appendix H. No specific sources of chlorinated benzenes have been identified in the Diagonal Way CSO/SD (111) basin. Chlorinated benzenes were detected at concentrations of 200 ug/kg (soil samples) and 1,000 ug/L (water samples) in the samples collected from the Janco-United property (Mann, C., 2 May 1988, personal communication).

Phenol (E1,500 ug/kg) and 4-methylphenol (E5,900 ug/kg) have also been identified as problem chemicals in the Diagonal Way CSO/SD (111) (see Figure 4-23). The concentration of phenol in the sediment sample was the highest concentration measured during the sampling program. Phenol is one of the most widely used organic chemicals. A total of about 2.5×10^9 lb of synthetic phenol were produced in the U.S. in 1985. An additional 50×10^7 lb were recovered from natural sources such as coal tar and petroleum fractionation (Chemical & Engineering News 1985). The primary use of phenol is in the production of synthetic resins and glues, but it is also an intermediate in the manufacture of other organic chemicals. Most phenolic resins are used as binders, particularly in the production of plywood and wood fiberboard (Kirk-Othmer 1985). Additional uses of phenol are presented in Appendix H. No specific sources of phenol have been identified in the Diagonal Way CSO/SD (111) basin. However, because of its widespread use there are probably multiple sources of phenol in the Diagonal Way CSO/SD (111) basin.

Specific sources of 4-methylphenol have not been documented in the Diagonal Way CSO/SD (111) basin. Uses of 4-methylphenol are presented in Appendix H. The Diagonal Way CSO/SD (111) basin is currently composed of a combination of residential, commercial, and industrial users. The only site that has been identified in the basin that may be a potential source of 4-methylphenol is the inactive 6th Ave. S. landfill. 4-Methylphenol was

identified as a problem chemical in another drain [Hanford CSO (W032)], which also serves part of the landfill. Groundwater may have infiltrated the drain lines and contributed to the contamination in the sediments in the drain.

4.3.8 Upper Duwamish Estuary

The Upper Duwamish Estuary study area has been divided into the following four sections to facilitate the discussion of the source sampling results (Figure 4-24):

- Section A - from the south end of Kellogg Island to the south end of Slip 2
- Section B - from the south end of Slip 2 to the Slip 4
- Section C - Slip 4
- Section D - from Slip 4 to the turning basin (project area boundary).

Section A--

Metals--Sediment samples were collected from three drains [(Duwamish SD, Brandon CSO (W041), and Graham SD] that discharge into Section A of the upper Duwamish estuary (see Figure 4-24). The results from the metals analyses of these sediments are summarized in Figure 4-25. HAET or 90th percentile concentrations were exceeded for seven metals (i.e., antimony, arsenic, cadmium, copper, lead, mercury, and zinc) in the Duwamish SD and six metals (i.e., cadmium, lead, mercury, nickel, selenium, and zinc) in the Brandon CSO (W041). No metals concentrations exceeded HAET or 90th percentile concentrations in the Graham SD sediment. The relative distribution of metals in the sediment from the Graham SD was similar to the relative distribution of metals in urban street dust (Table 4-9). Therefore, it is likely that metals found in the sediments were largely contributed from nonpoint sources such as urban runoff.

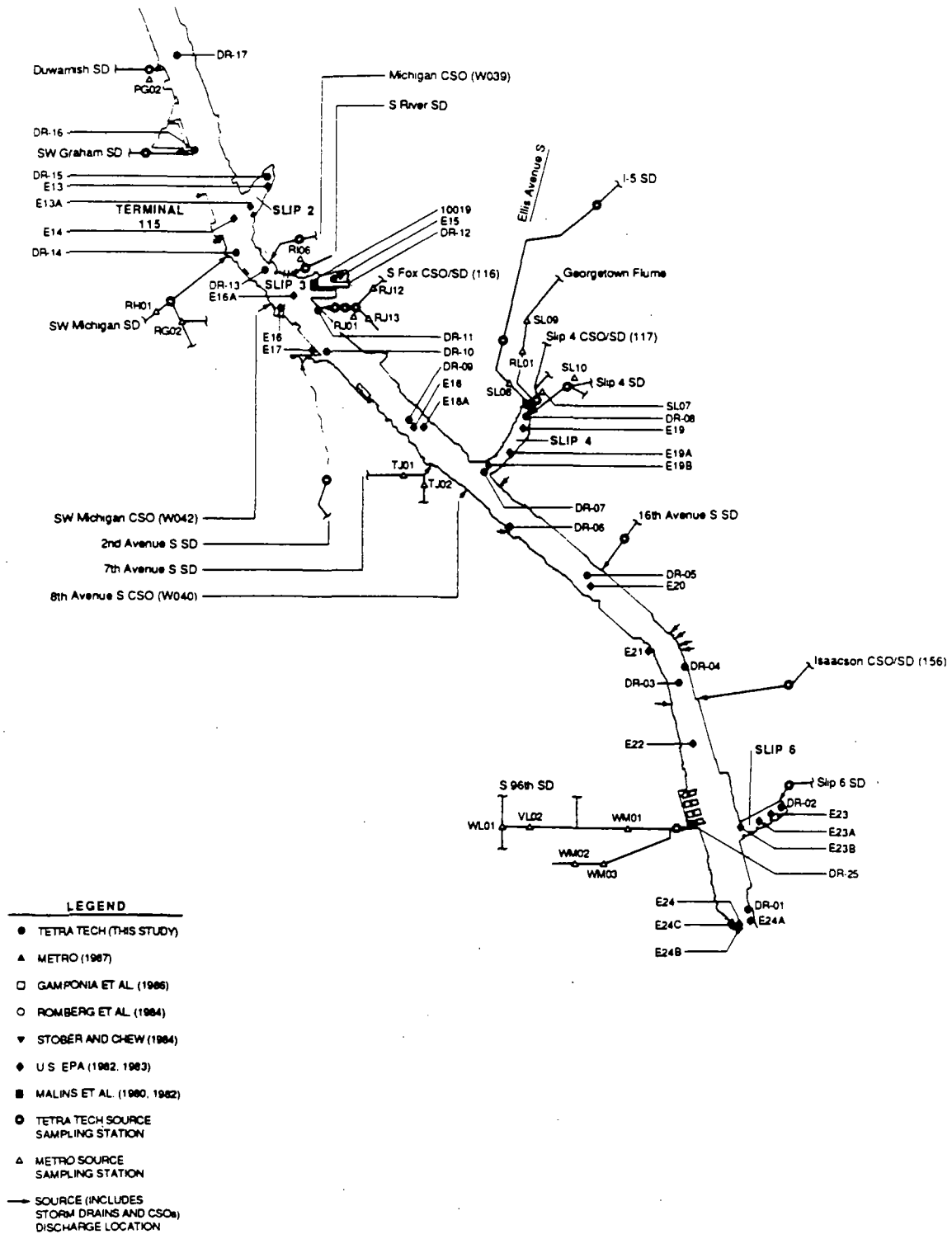


Figure 4-24. Locations of offshore and drain sampling stations, CSOs, and storm drains in the Upper Duwamish Estuary study area.

CONCENTRATION (mg/kg dry weight)

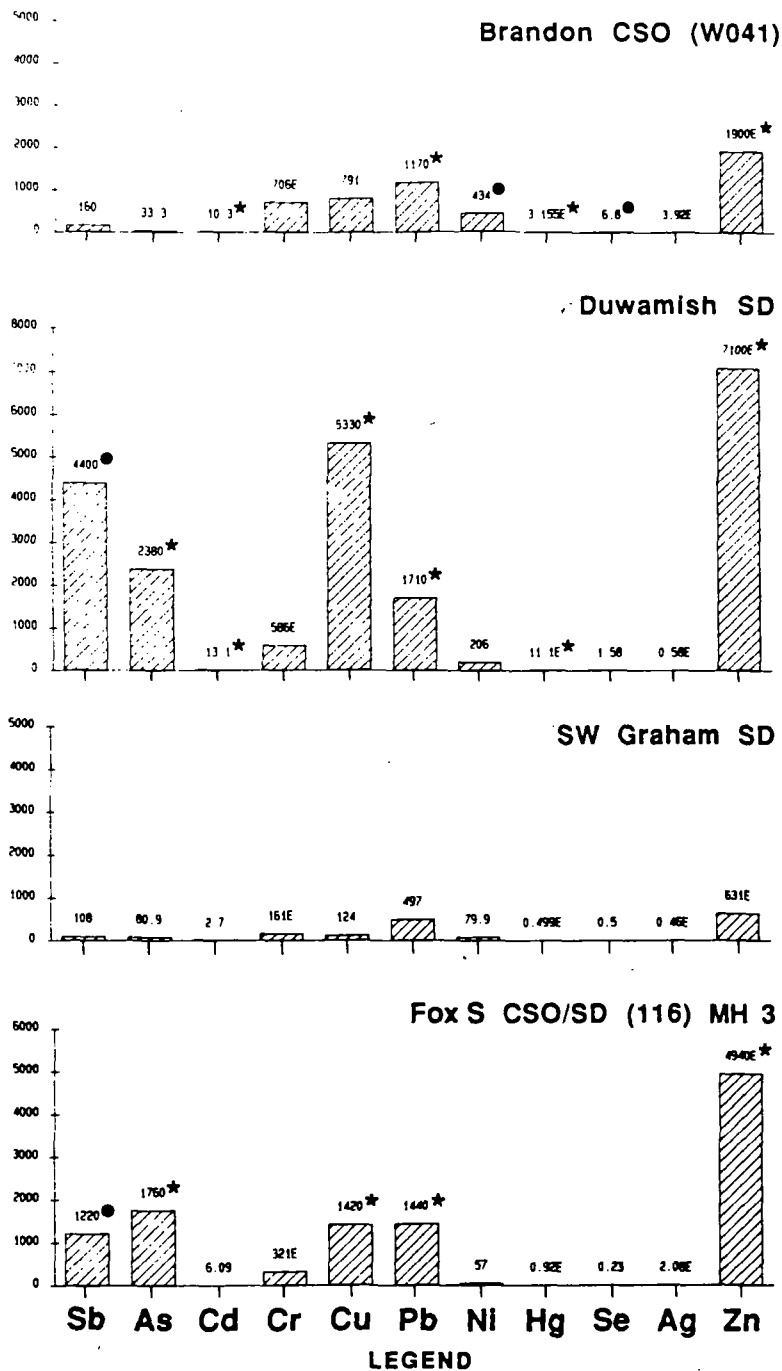


Figure 4-25. Concentrations of metals in sediments collected from drains discharging into the Duwamish River, Section A.

TABLE 4-9. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS
FROM DRAINS DISCHARGING INTO THE UPPER DUWAMISH ESTUARY, SECTION A

Metals	Brandon CSO (W041)	Duwamish SD	Graham SD	Street Dust ^a
Antimony	3	20	6	<1
Arsenic	<1	11	5	1-5
Cadmium	<1	<1	<1	<1
Chromium	14	3	10	2-15
Copper	15	25	7	4-12
Lead	22	8	29	30-64
Mercury	<1	<1	<1	<1
Nickel	8	1	5	2-4
Silver	<1	<1	<1	<1
Zinc	36	33	37	14-54
Total metals (mg/kg)	5,200 ^b	21,700 ^b	1,680 ^b	680-1,800 ^c

^a Commercial and industrial sites (Galvin and Moore 1982).

^b Values reported as dry-weight concentrations.

^c Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

The Duwamish SD sediments contained antimony, arsenic, mercury, and zinc at concentrations higher than all the other drains sampled. This drain also had the largest number of problem metals (7) of any drain in the study area. The concentrations of the problem metals identified in the Duwamish SD sediment sample were 1.3-40 times greater than the concentrations measured in the other drains in Section A, and were as much as 3 orders of magnitude greater than the concentrations reported in urban street dust (Galvin and Moore 1982).

The layout of the Duwamish SD system and drainage basin boundaries are not well defined. It appears that the system serves the area east of West Marginal Way and north of Port of Seattle Terminal 115 property (see Figure 4-24). This area is currently occupied by a shipbuilding and repair facility and a construction company.

The elevated metal concentrations in the sediments from the Duwamish SD may have been related to sandblasting activities at the shipyard. In the past, slag from a copper smelter in British Columbia was used as sandblast grit by many of the shipyards in the project area (Dexter et al. 1981). Limited chemical analyses indicate that the slag contained copper at concentration of about 1,000 mg/kg (Dexter et al. 1981). Although insufficient data are available to characterize the British Columbia smelter slag, data are available (Table 4-10) for slag from a copper smelter in Tacoma (Reall, D., 21 January 1986, personal communication). Slag from the Tacoma copper smelter was used extensively for sandblasting by shipyards in the Commencement Bay area (Tetra Tech 1986a). Comparison between the relative distribution of metals in the drain sediments in Commencement Bay and the Tacoma smelter slag show that the same metals (i.e., antimony, arsenic, copper, and zinc) predominate in both samples (see Table 4-10). This suggests that sandblast grit from historical operations at the shipyard was the likely source of contamination in the Duwamish SD sediments. The shipyard has been identified as a high priority on Ecology's list of hazardous waste sites (WEC Alert! 1987) because of metals contamination. Further discussion of the apparent connection between the contaminants found

TABLE 4-10. CONCENTRATIONS OF METALS IN
COPPER SLAG FROM THE TACOMA SMELTER

Metals	(mg/kg)
Antimony	6,400
Arsenic	7,300
Cadmium	5
Chromium	1,200
Copper	4,100
Lead	3,600
Nickel	130
Silver	19
Zinc	6,100

Reference: Reall, D., 21 January 1986,
personal communication.

in slag, contaminants observed in drains serving shipyard facilities, and contaminants found in offshore sediments, is provided in Section 4.4.3.

In the past, housekeeping procedures practiced by shipyards were inadequate to control the release of spent sandblast grit to the environment. Ecology is currently working with the shipyards to inform them of the pollution problems associated with shipyard activities. Ecology's program includes workshops to inform shipyard owners of best management practices. In addition, all shipyards, if not already permitted, will be required to apply for a NPDES permit. Permit requirements for shipyards are being updated and will include best management practices to prevent sandblast grit and other materials from entering the waterways, as well as monitoring for oil, grease, turbidity, and metals (Morrison, S., 25 August 1987, personal communication).

Sediments collected from the Brandon CSO (W041) exceeded HAET for cadmium, lead, mercury, and zinc (see Figure 4-25). Nickel and selenium exceeded the 90th percentile concentrations (223 mg/kg and 2.6 mg/kg, respectively). The concentrations of nickel (434 mg/kg) and selenium (96.8 mg/kg) were the highest concentrations measured during the drain sampling program. Although the relative distribution of metals in the sediments from the Brandon CSO (W041) was generally similar to the relative distribution of metals in urban street dust (see Table 4-9), the total concentration of metals in the drain sediments was about 5 times greater than the concentration reported in urban street dust (Galvin and Moore 1982). This difference in metals concentrations suggests one or more sources other than typical urban runoff.

The Brandon CSO (W041) is located across the Duwamish River and approximately 1,500 ft downstream of the shipyard described above (see Figure 4-24). Therefore, it is unlikely that metals concentrations in the CSO sediments were related to shipyard activities. Potential metals sources that have been identified in the basin include an abandoned landfill that has allegedly received acids, heavy metals, and other inorganic materials (U.S. EPA, 22 October 1987, personal communication), and five facilities (a metal plating firm, a graphics company, a glass container manufacturer, a

tank cleaning service, and an aviation equipment manufacturer) that are permitted under Metro's industrial pretreatment program to discharge wastewater to the sanitary sewer in the Brandon CSO (W041) service area (Hildebrand, D., 16 October 1987, personal communication). Three of the facilities (the metal plater, the tank cleaning service, and the aviation equipment manufacturer) are considered major dischargers. Effluent from these three major dischargers is periodically monitored by Metro for cadmium, chromium, nickel, lead, and zinc. For the period May 1985 through April 1986, the metals concentrations in the effluent from these three facilities ranged from 0.004 to 0.04 mg/L of cadmium, 0.02 to 5.42 mg/L of chromium, 0.02 to 0.81 mg/L of lead, 0.38 to 22.1 mg/L of nickel, and 0.03 to 3.93 mg/L of zinc (Hildebrand, D., 16 October 1987, personal communication). However, the distribution of these metals between dissolved and particulate phases in the effluent and the relative percent loading in the CSO discharges is unknown. Therefore, it is not possible to identify specific sources responsible for the metals contamination observed in the Brandon CSO (W041).

Organic Compounds--The organic compounds that were detected most frequently in the drains discharging into Section A are summarized in Figure 4-26. PAH (2-methylnaphthalene) and 4-methylphenol were identified as problem chemicals in the Brandon CSO (W041). The Brandon CSO (W041) serves an area of about 250 ac in South Seattle (see Map 2 in Map Appendix).

No organic compounds have been identified as problem chemicals in the Duwamish SD and the SW Graham SD. The concentration of most organic compounds in the SW Graham SD sediments were below 200 ug/kg. HPAH and LPAH were the major organic constituents in the sediments from the Duwamish CSO/SD. LPAH consisted entirely of phenanthrene (2,100 ug/kg) and anthracene (E320 ug/kg), both of which are commonly found in urban street dust (Galvin and Moore 1982). The principal HPAH compounds found in the Duwamish SD sediment were fluoranthene, pyrene, benzo(a)pyrene, and benzo(a)anthracene. These HPAH compounds are also typically found in urban street dust. Therefore, the PAH found in the Duwamish SD sediment sample are probably associated with urban runoff rather than a specific point source.

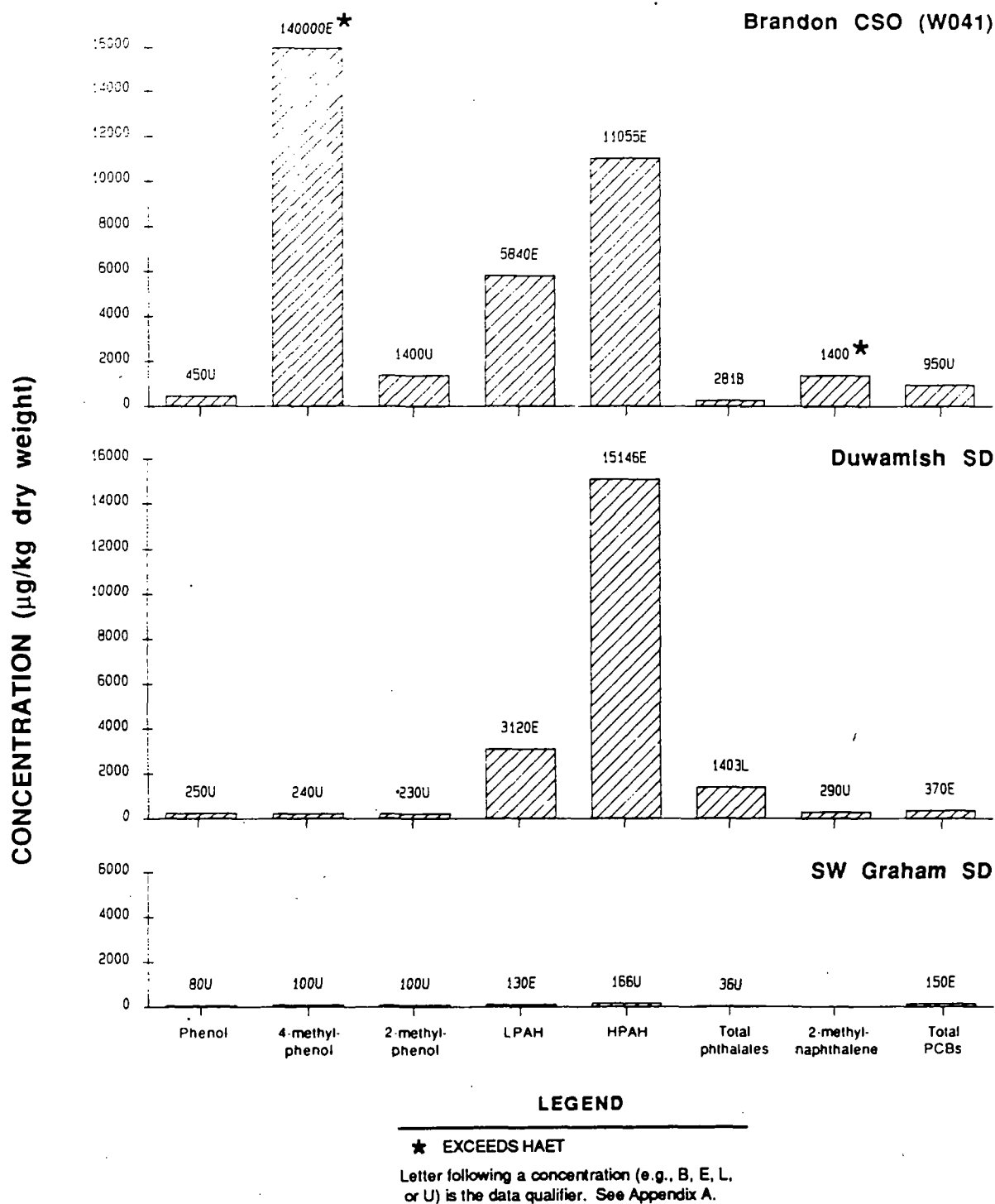


Figure 4-26. Concentrations of selected organic compounds in sediments collected from drains discharging into the Upper Duwamish Estuary, Section A.

The concentration of 4-methylphenol (E140,000 ug/kg) measured in the sediment from the Brandon CSO (W041) was the highest concentration measured during the CSO/SD sampling program. Uses of 4-methylphenol are summarized in Appendix H. The source of 4-methylphenol in the sediment from the Brandon CSO (W041) is unknown.

The concentration of 2-methylnaphthalene in the sediment from the Brandon CSO (W041) (1,400 ug/kg) exceeded the HAET (670 ug/kg). 2-Methylnaphthalene is a PAH, but was not analyzed for in the street dust samples by Galvin and Moore (1982). However, the relative distribution of other LPAH in the Brandon CSO (W041) sediments was similar to the relative distribution reported in urban street dust. Phenanthrene was the major LPAH component, constituting 87 percent of the total LPAH. Anthracene (E420 ug/kg) comprised the remaining 13 percent. Naphthalene and alkylated naphthalenes have been identified as a primary constituent of crankcase oil. In addition, naphthalene is used in chemical intermediates for the manufacture of dyes, insect repellants, synthetic resins, and tanning agents; manufacture of solvents and lubricants; and constituents in motor fuels, celluloid, lampblack, and smokeless powder (Kirk-Othmer 1985). It is likely that 2-methylnaphthalene contamination was associated with nonpoint sources such as urban runoff.

Section B--

Metals--Sediment samples were collected from five CSOs and storm drains [Michigan SD, 2nd Ave. S. SD, S. River SD, Michigan CSO (W039), Fox S. CSO/SD (116)] that discharge into the Duwamish River in Section B (see Figure 4-24). With the exception of the SW Michigan CSO (W042), all CSOs and city storm drains in the area were sampled.

Results from the metals analyses of the drain sediment samples are summarized in Figure 4-27. There were no problem metals identified in the Michigan SD or the 2nd Ave. S. SD. The relative distribution of metals in these two drains was similar to the relative distribution of metals in urban street dust (Table 4-11), indicating that metals contamination in these two drains was caused by nonpoint sources such as urban runoff. Sediments from

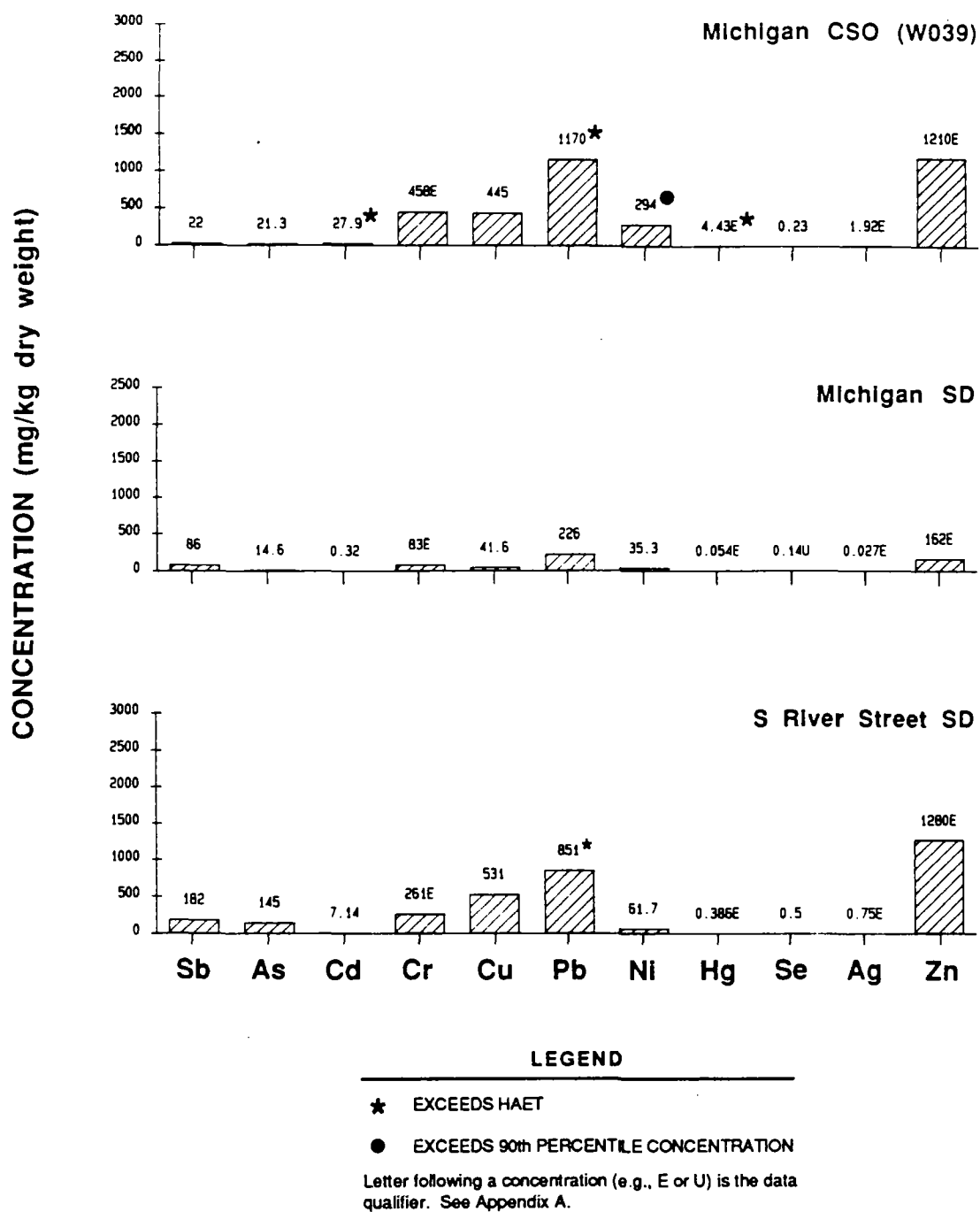
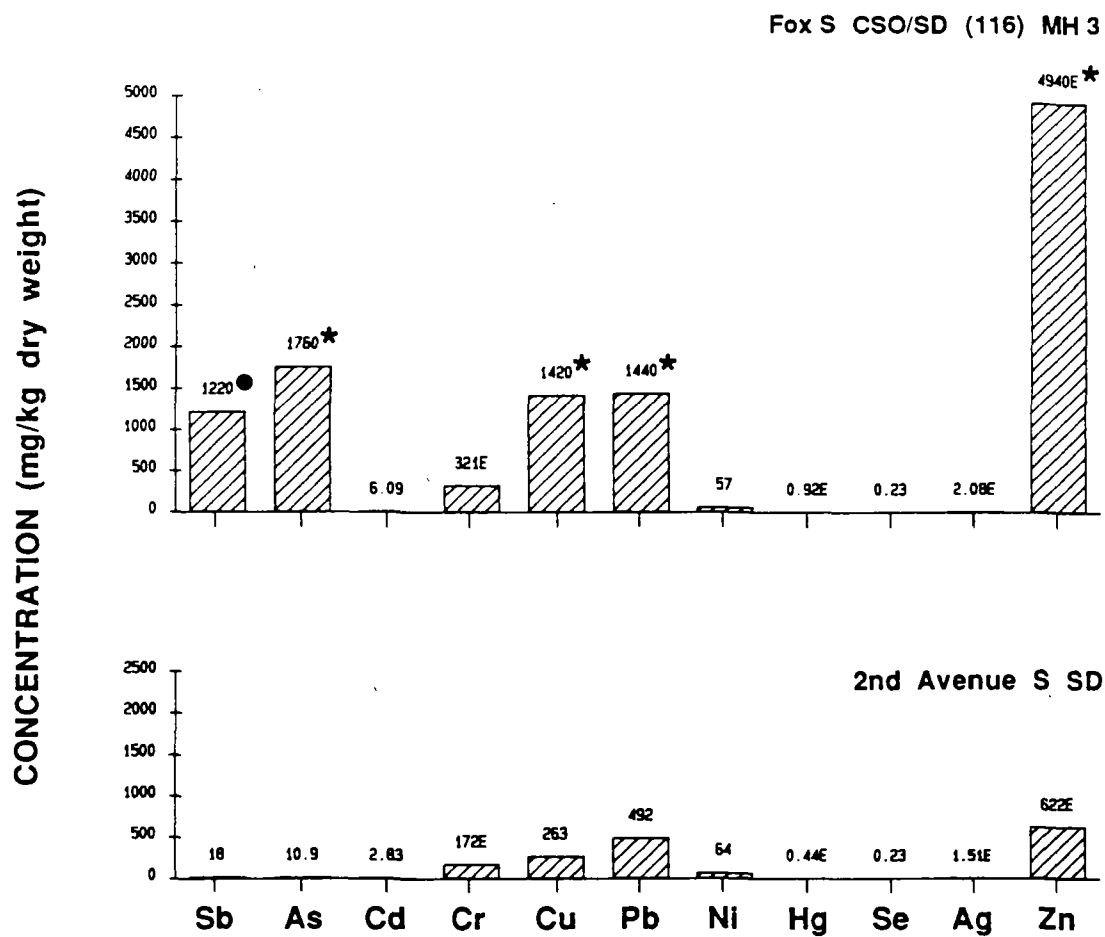


Figure 4-27. Concentrations of metals in sediments collected from drains discharging into the Duwamish River, Section B.



LEGEND

* EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-27. (Continued).

TABLE 4-11. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS FROM DRAINS DISCHARGING INTO THE UPPER DUWAMISH ESTUARY, SECTION B

Metals	Michigan SD	2nd Ave. S. SD	River SD	Michigan CSO	Fox S. CSO/SD (116)-MH3 ^a	Fox S. CSO/SD (116) Catch Basin Sediments ^b	Street Dust ^c	Copper Slag ^d
Antimony	13	1	5	<1	11	NA ^e	<1	22
Arsenic	2	<1	4	<1	16	14-19	1-5	25
Cadmium	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	13	10	8	13	3	<1-1	2-15	4
Copper	6	16	16	12	13	21-26	4-12	14
Lead	35	30	26	32	13	6-11	30-64	12
Mercury	<1	<1	<1	<1	<1	<1	<1	NA
Nickel	5	4	2	8	<1	<1	2-4	<1
Silver	<1	<1	<1	<1	<1	NA	<1	<1
Zinc	25	38	39	33	44	44-58	14-54	21
Total metals (mg/kg)	650 ^f	1,650 ^f	3,320 ^f	3,660 ^f	11,200 ^f	10,500-28,400 ^f	678-1,800 ^g	28,900 ^f

^a MH3 is located at the intersection of South Brighton St. and Fox S.

^b Metro samples from 25 February 1985 (Sample, T., 23 October 1987, personal communication).

^c Commercial and industrial sites (Galvin and Moore 1982).

^d Composition of slag from copper smelter in Tacoma (Reall, D., 21 January 1986, personal communication).

^e NA = Not analyzed.

^f Values reported as dry-weight concentrations.

^g Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

the remaining drains exceeded the HAET or 90th percentile concentration for the following metals:

- S. River SD - lead
- Michigan CSO (W039) - cadmium, lead, mercury, and nickel
- Fox S. CSO/SD (116) - arsenic, copper, lead, and zinc.

Lead was the only problem metal detected in all three drains (see Figure 4-27).

The lead concentration in the sediment from the S. River SD (851 mg/kg) was within the range reported in urban street dust (90-1,300 mg/kg; Galvin and Moore 1982). In addition, the relative distribution of metals in the drain sediments was similar to the relative distribution found in street dust (see Table 4-11). Therefore, it is likely that the lead contamination in the S. River SD was caused by urban runoff rather than a specific point source discharge.

The relative distribution of metals in the Fox S. CSO/SD (116) was different from the relative distribution of metals in urban street dust (see Table 4-11). In particular, the relative abundance of antimony (11 percent) and arsenic (16 percent) was higher and the relative abundance of lead (13 percent) was lower than in urban street dust. The Fox S. CSO/SD (116) serves approximately 30 ac located on the west side of E. Marginal Way S., between Slip 3 and S. Myrtle St. (see Map 3 in Map Appendix). The lower portion of the basin, bounded by Slip 3, S. Willow St., Fox S. and the Duwamish River, is occupied by Marine Power and Equipment, a shipbuilding and repair facility.

Shipbuilding and repair facilities in the Elliott Bay project area have historically used slag from a copper smelter in British Columbia as sandblasting/grit (Dexter et al. 1981). Copper slag is relatively high in antimony, arsenic, copper, and zinc (see Table 4-10), which were the same metals that exceeded HAETs in the Fox S. CSO/SD (116) sediments. The

relative distribution of metals in the drain sediments was also similar to the relative distribution of metals in copper slag (see Table 4-11). This suggests that historical use of copper slag at the shipbuilding facility was probably the source of contamination in the Fox S. CSO/SD. Further discussion of sources is presented in Section 4.5.

The data presented in Table 4-11 are from sediments collected from MH3 on Fox S. CSO/SD (116), which is located at the entrance of the shipyard. Sediments collected from MH1 (near the outfall) and MH2 (midway across the shipyard) showed similar results (Figure 4-28) (see Section 4.4.3). However, of the three manholes sampled, MH3 exhibited the highest concentrations of metals and the largest number of chemicals that exceeded HAET or 90th percentile concentrations.

The contamination found in MH3, on the upstream border of Marine Power and Equipment shipyard property, indicates that the contamination from sandblasting activities has extended offsite into the upper drainage basin of Fox S. CSO/SD (116). PSAPCA investigated the shipyard in the early 1980s and observed that fugitive dust emissions from the facility had contaminated pancake mix produced at a nearby company (Sample, T., 16 March 1988, personal communication). The shipyard was issued a civil penalty for air emissions of particulate material from their sandblasting operations in July 1982 (Anonymous, 16 March 1988, personal communication). In addition, during the Elliott Bay Action Program source sampling investigation, sandblast grit material was observed throughout the shipyard area.

Metro also reported that sandblast grit was present in and around the shipyard in 1984 when samples were collected from the Fox S. CSO/SD (116) (Sample, T., 16 March 1988, personal communication). As part of their sampling effort, Metro collected sediment samples from nine catch basins on Marine Power and Equipment shipyard property that discharge into the Fox S. CSO/SD (116). Metro found that the sediments were contaminated with arsenic, copper, lead, and zinc (Table 4-12). The relative distribution of metals in the catch basin sediments was similar to the relative distribution in the Fox S. CSO/SD (116) manhole samples and the copper slag material (see Table 4-11).

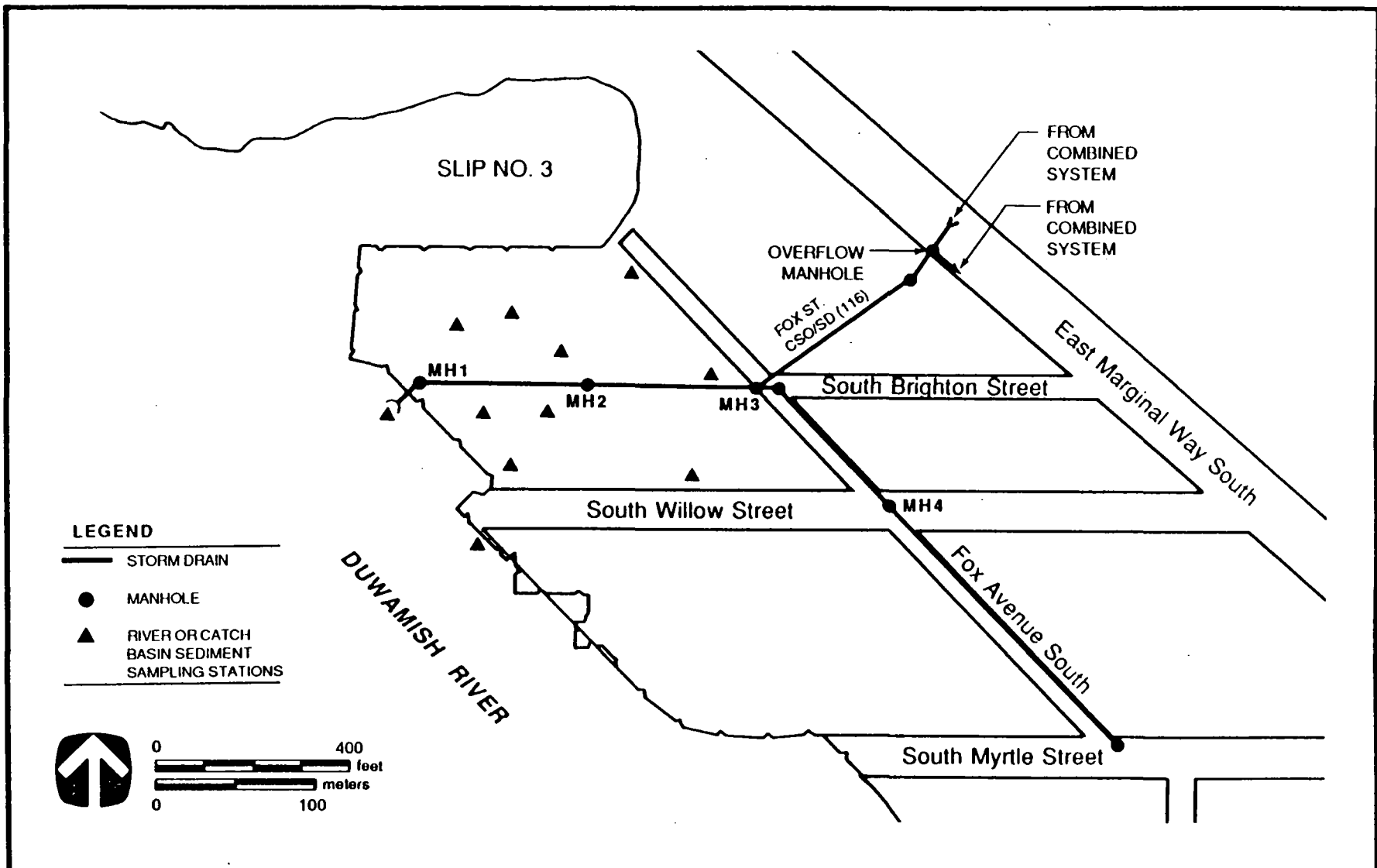


Figure 4-28. Metro sampling stations on Fox S. CSO/SD (116).

TABLE 4-12. SUMMARY OF METALS CONCENTRATIONS IN SEDIMENT
SAMPLES FROM FOX S. CSO/SD (116) AND SURROUNDING AREA (mg/kg)^a

Sampling Location	Date Sampled	Arsenic	Cadmium	Copper	Lead	Zinc
<u>Fox S. CSO/SD (116)</u>						
MH3 ^b	4/5/84	3,800	4.4	1,200	1,400	5,600
	2/25/85	1,200	6.7	900	900	2,300
	3/27/86	1,200	5.4	710	730	2,300
MH4 ^b	3/27/86	110	6.2	380	620	850
MH1 ^c	9/27/85	893	9.92	2,290	1,110	5,980
MH2 ^c	9/27/85	1,050	2.56	716	894	3,020
MH3 ^c	9/27/85	1,760	6.09	1,420	1,440	4,940
<u>Duwamish River sediments</u>						
Upstream of drain	4/18/84	21	<0.3	60	51	160
Offshore of drain	4/18/84	210	0.5	290	150	1,000
<u>Sediment samples from catch basins^{b, d}</u>	2/25/85	1,000- 3,900 ^e	9.5- 19 ^e	2,300- 7,600 ^e	950- 1,900 ^e	6,200- 15,000 ^e
		(2,200) ^f	(14) ^f	(5,000) ^f	(1,400) ^f	(10,000) ^f
<u>Mean street dust levels^g</u>	--	25	1.0	93	520	310

^a Stations shown on Figure 4-31.

^b Metro samples (Sample, T., 23 October 1987, personal communication).

^c This study.

^d Catch basins connected to the Fox S. drain downstream of MH3.

^e Range in concentration for nine stations.

^f Mean value from n=9.

^g Galvin and Moore (1982).

The relative distribution of metals in the sediment samples from the Michigan CSO (W039) was similar to the relative distribution found in urban street dust (see Table 4-11). However, with the exception of lead, the concentrations of the problem metals (i.e., cadmium, lead, mercury, and nickel) were generally 1-2 orders of magnitude greater than the concentrations reported in urban street dust (Galvin and Moore 1982), which indicates that sources other than urban runoff exist in the Michigan CSO (W039) basin:

<u>Chemical</u>	Michigan CSO (W039) <u>(mg/kg)</u>	Street Dust <u>(mg/kg)</u>
Cadmium	27.9	0.6-2.0
Lead	1,170	90-1,300
Mercury	4.43	0.03-0.18
Nickel	294	20-44

In general, nickel and cadmium have similar uses (see Appendix H). Therefore, the nickel and cadmium contamination observed in the Michigan CSO (W039) may have been caused by the same sources. The mercury contamination in Michigan CSO (W039) sediments appears to have been caused by different sources, because mercury is used in different products than are nickel and cadmium (see Appendix H).

No specific sources of these contaminants have been documented in the Michigan CSO (W039) basin. Because of the heavy industrial activity in the basin, it is likely that there are multiple sources. The list of potential sources in the basin, based on information obtained from Metro, Ecology, and U.S. EPA, include eleven facilities permitted to discharge waste to the sanitary sewer in the Michigan CSO (W039) basin under Metro's industrial pretreatment program. The potential sources include metal finishers, a glass products manufacturer, an industrial organic chemical manufacturer, a trucking company, a manufacturer of adhesives, a bottling company, a manufacturer of household and industrial chemicals, an ice manufacturer, and a manufacturer of aviation equipment. Potential sources also include six facilities on U.S. EPA's CERCLIS [i.e., a TSD facility, an industrial chemical manufacturer, two metal finishers, and two paint manufacturers; U.S. EPA, 22 October 1987, personal communication]. Six of the industrial

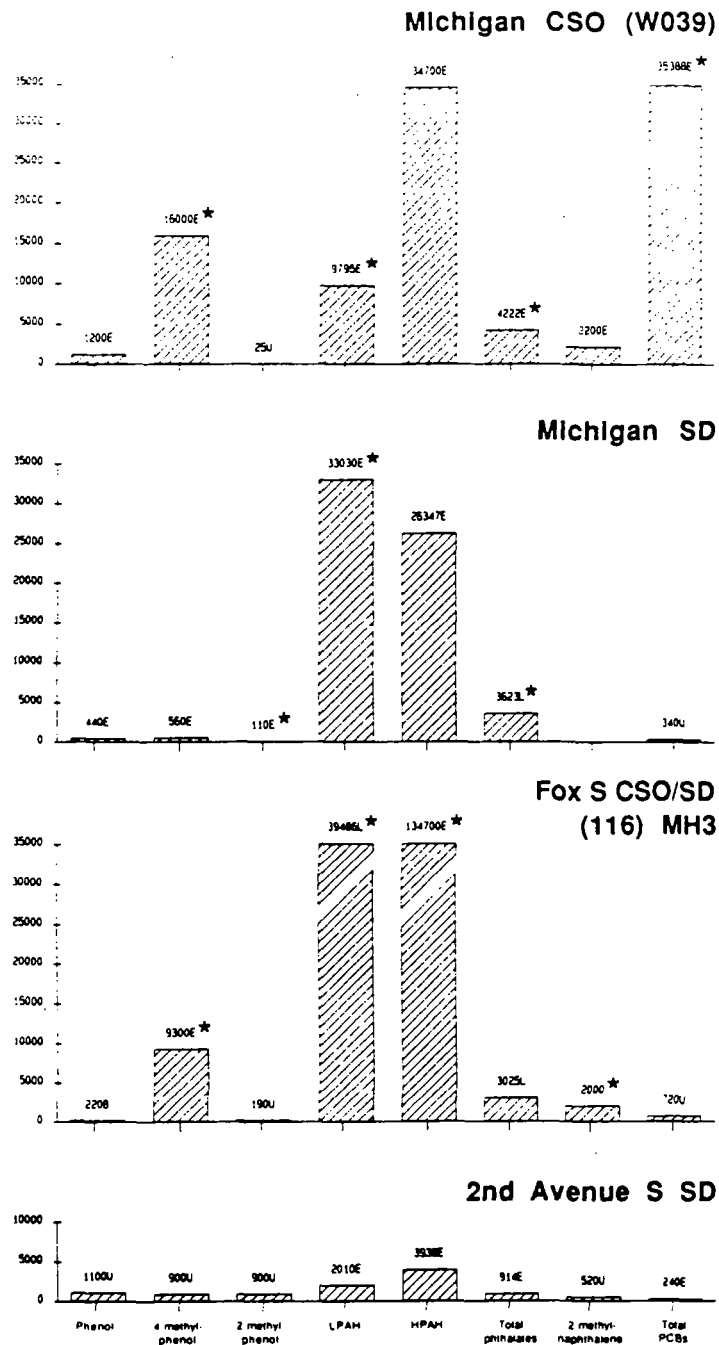
pretreatment facilities are considered major dischargers by Metro (Hildebrand, D., 23 December 1987, personal communication). Effluent from these facilities is periodically monitored by Metro for cadmium, chromium, copper, nickel, lead, and zinc. The TSD facility has been identified as having a potential for surface water contamination because of heavy metals stored onsite.

In addition, illegal dumping and soil contamination have been observed at the TSD site (U.S. EPA, 22 October 1987, personal communication). The manufacturer of household and industrial chemicals was inspected by Ecology in 1987 and instructed to provide better containment for its acid and diesel fuel storage areas (Ecology 1987). Contamination of sewers and storm drains has been observed at both metal plating facilities (U.S. EPA, 22 October 1987, personal communication). In addition, illegal dumping and offsite damage have been observed at one of the metal finishers. One of the paint manufacturers has been classified as a low priority for future investigations. Groundwater and soil contamination have been observed at the other paint manufacturing facility (U.S. EPA, 22 October 1987, personal communication).

Organic Compounds--The organic compounds detected most frequently in the drains discharging into the upper Duwamish Estuary, Section B are summarized in Figure 4-29. PAH, phthalates, phenols, PCBs, p,p'-DDT, p,p'-DDE, volatile organic compounds, and chlorinated benzenes have been identified as problem chemicals in the drains discharging into Section B:

- Michigan SD - naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, LPAH, dibenzofuran, indeno(1,2,3-c,d)pyrene, total phthalates, 2-methylphenol, and 2,4-dimethylphenol
- Michigan CSO (W039) - acenaphthene, indeno(1,2,3-c,d)pyrene, LPAH, 1-methylphenanthrene, chlorinated benzenes, 2-methylnaphthalene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, total phthalates, butyl benzyl phthalate, p,p'-DDE, p,p'-DDT, PCBs, 4-methylphenol, and total xylenes

CONCENTRATION ($\mu\text{g/kg}$ dry weight)



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., B, E, L, or U) is the data qualifier. See Appendix A.

Figure 4-29. Concentrations of selected organic compounds in sediments collected from drains discharging into the Upper Duwamish Estuary, Section B.

- Fox S. CSO/SD (116) - naphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, dibenzofuran, 2-methylnaphthalene, 1-methylphenanthrene, benzofluoranthenes, 3-methylphenanthrene, 2-methylphenanthrene, indeno(1,2,3-c,d)pyrene, LPAH, HPAH, di-n-octyl phthalate, total phthalates, 4-methylphenol, 1,1-dichloroethane, trans-1,2-dichloroethene, and benzoic acid.

The 2nd Ave. S. SD was the only drain in Section B that did not exceed an HAET or a 90th percentile concentration for an organic compound. The sediments collected from the Fox S. CSO/SD (116) had the largest number of organic compounds (30) at concentrations exceeding HAET. The Fox S. CSO/SD also had the largest number of chemicals (17) whose concentration was the highest reported during the drain sampling program. Fourteen of these compounds were PAHs, two were phthalates, and one was benzoic acid.

PAH compounds were the predominant organic compounds found in the drain sediments from Section B. The ratio of HPAH to LPAH ranged from 0.80 to 3.5 in the drain sediments. In addition, the M/P ratio of which can be used to distinguish between combusted vs. noncombusted fuel sources, indicates that the PAH contamination in all of the drains was primarily from combusted fuel sources (Prah1 and Carpenter 1983):

	<u>HPAH/LPAH</u>	<u>MP/P</u>
Fox S. CSO/SD (116)-MH1	2.7	0.41
Fox S. CSO/SD (116)-MH3	3.4	0.27
Michigan SD	0.80	0.007
Michigan CSO (039)	3.5	0.40
Combusted fuel mixtures	---	0.5-1.0
Noncombusted fuel mixtures	---	2-6

With the exception of the Michigan SD, the HPAH/LPAH and MP/P ratios in the drains in Section B were fairly similar. The difference in the PAH composition in the Michigan SD indicates that there may have been different PAH sources in this basin than in the other two drainage basins.

The relative distribution of individual PAH compounds in the drain samples are summarized in Table 4-13. Phenanthrene was the predominant LPAH found in the drain sediments (44-100 percent). With the exception of the 2nd Ave. S. SD, the relative abundance of phenanthrene in the drain sediments was generally lower than the relative abundance measured in street dust (68-100 percent). LPAH in the 2nd Ave. S. SD consisted entirely of phenanthrene, which was similar to the results reported for urban street dust (Galvin and Moore 1982). In addition, the concentration of LPAH in the 2nd Ave. S. SD (490 ug/kg) was within the range reported for urban street dust (280-3,400 ug/kg). Therefore, it is likely that LPAH in 2nd Ave. S. SD was contributed largely from urban runoff. However, LPAH sources other than urban runoff apparently contributed to the LPAH contamination in the Michigan CSO, Michigan SD, and Fox S. CSO/SD (116). The concentration of LPAH in the drain sediments was as much as 140 times greater than the LPAH concentration in street dust samples.

With the exception of benzo(k)fluoranthene, which constituted 25 percent of the HPAH in the Michigan SD, fluoranthene (17-24 percent), pyrene (18-26 percent), and chrysene (14-21 percent) were the predominant HPAH compounds measured in the drain sediments in this area. The relative distribution of HPAH was similar to the relative distribution in urban street dust samples. However, the total concentration of HPAH in sediments from the Fox S. CSO/SD (116), Michigan CSO (W039), and Michigan SD were 3-170 times greater than the concentrations measured in urban street dust, which suggests that there were sources other than urban runoff that contributed to the HPAH contamination in these drains. HPAH contamination in the 2nd Ave. S. SD appeared to be contributed primarily from urban runoff.

No specific sources of LPAH and HPAH have been documented for the drains discharging into Section B. Potential sources that have been identified in the Michigan CSO by U.S. EPA, Ecology, and Metro are summarized in Table 4-14. A few of the potential sources in the Michigan CSO basin may have PAHs associated with their operations: an oil recycling facility, an aircraft testing facility, a TSD facility, and a chemical recycling facility. The TSD facility in the Michigan SD basin is a potential source

TABLE 4-13. RELATIVE PERCENT DISTRIBUTION OF PAH IN SEDIMENTS FROM DRAINS DISCHARGING INTO UPPER DUWAMISH ESTUARY, SECTION B

PAH	Michigan CSO (W039)	Michigan SD	Fox S. CSO/SD (116)-MH1	Fox S. CSO/SD (116)-MH2	Fox S. CSO/SD (116)-MH3	2nd Ave. S. SD	Street Dust ^a
LPAH							
Naphthalene	14	27	<1	5	6	<1	0
Acenaphthylene	<1	3	<1	<1	<1	<1	0
Acenaphthene	10	5	6	<1	7	<1	0
Fluorene	17	8	7	<1	14	<1	0
Phenanthrene	44	48	46	67	51	100	100
Anthracene	14	9	41	28	22	<1	0
TOTAL (ug/kg)	9,790 ^b	33,000 ^b	8,240 ^b	3,580 ^b	39,400 ^b	490 ^b	1,200-2,600 ^c
HPAH							
Fluoranthene	17	23	24	18	21	21	26-48
Pyrene	20	22	24	22	18	26	26-52
Benzo(a)anthracene	8	12	8	10	10	8	0-12
Chrysene	14	17	16	16	16	21	0-19
Benzo(b)fluoranthene	11	<1	6	6	8	8	0
Benzo(k)fluoranthene	5	25	8	8	10	10	0-16
Benzo(a)pyrene	6	<1	6	7	7	7	0-9
Indeno(1,2,3-c,d)pyrene	8	<1	4	6	4	<1	0
Dibenzo(a,h)anthracene	3	<1	1	3	1	<1	0
Benzo(g,h,i)perylene	7	<1	3	5	4	<1	0
TOTAL (ug/kg)	34,700 ^b	26,300 ^b	22,600 ^b	11,500 ^b	134,700 ^b	3,730 ^b	3,100-9,480 ^c

^a Commercial and industrial sites (Galvin and Moore 1982).

^b Values reported as dry-weight concentrations.

^c Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

TABLE 4-14. LIST OF POTENTIAL CONTAMINANT SOURCES
IDENTIFIED IN THE BASINS OF DRAINS DISCHARGING INTO SECTION B
OF THE UPPER DUWAMISH ESTUARY

Michigan SD:

- A TSD facility has been included on U.S. EPA's list of hazardous waste sites that are currently under investigation. However, the facility is no longer in operation (U.S. EPA, 22 October 1987, personal communication).

Michigan CSO (W039):

- Six facilities on U.S. EPA's CERCLIS (U.S. EPA, 22 October 1987, personal communication):
 - 1) A chemical recycling facility that has illegally disposed of hazardous materials. Contamination of soil and groundwater have been identified as potential problems at this site.
 - 2) A paint manufacturer with observed soil contamination and potential for groundwater contamination.
 - 3) A paint manufacturer with low potential for contamination.
 - 4) A metal finisher that operates a solvent recycling system that has allegedly contaminated the storm drains and sanitary sewer systems.
 - 5) A metal finisher that has reportedly illegally disposed of hazardous materials. Materials handled at the facility include acids, metals, solvents, and organic compounds. Soil and offsite contamination have been observed at this facility.
 - 6) A distributor of industrial, inorganic chemicals. Soil and surface water contamination have been observed at this site.
- Twelve facilities permitted under Metro's industrial pretreatment program to discharge wastes to the sanitary sewer system (Hildebrand, D., 23 December 1987, personal communication)
 - Seven of the twelve (a chemical recycler, a trucking company, two metals finishers, a glass products manufacturer, a manufacturer of aviation equipment, and a paint manufacturer) are considered major dischargers. Effluent for these facilities is periodically monitored by Metro for Cd, Cr, Cu, Pb, Hg, and Zn.
- An aircraft testing facility that has been included on Ecology's list of hazardous waste sites (WEC Alert! 1987) because of lead and PCB contamination.
- An oil recycling facility. Spills have been reported onsite and Ecology is requiring the facility to install better containment structures (Ecology 1987).

Fox S. CSO/SD (116):

- Marine Power and Equipment has been identified as a source of metals for sandblasting operators (Sample, T., 16 March 1988, personal communication).
-

of PAH. No potential sources of PAH have been identified in the Fox S. CSO/SD (116) basin.

The concentrations of LPAH and HPAH compounds in the three manholes sampled on the Fox S. CSO/SD (116) (MH1 - near outfall, MH2 - midway across Marine Power and Equipment property, and MH3 - at entrance to Marine Power and Equipment property) suggest that the source of PAH originated in the upper portion of the basin, upstream of MH3:

	<u>LPAH (ug/kg)</u>	<u>HPAH (ug/kg)</u>
MH1	E8,240	E22,580
MH2	E3,580	E11,500
MH3	E39,400	E134,700

The PAH concentration at the upstream station (MH3) was 10 times greater than the concentrations measured at the two downstream manholes.

In addition to LPAH and HPAH, other PAH (i.e., methylphenanthrenes and 2-methylnaphthalene) and PAH-related (i.e., dibenzofuran and 1,1'-biphenyl) compounds have been identified as problem chemicals in the Michigan SD, Michigan CSO (W039), and Fox S. CSO/SD (116). These contaminants probably originated from similar sources as the LPAH and HPAH compounds. Methylphenanthrenes and 2-methylnaphthalene have been discussed in previous sections. These compounds are components of fossil fuels and are commonly present in combustion-related sources (Prah1 and Carpenter 1983).

The highest concentrations of dibenzofuran in drain sediments were consistently found in drains that had the highest concentrations of PAH [e.g., Michigan SD, Fox S. CSO/SD (116), Interbay CSO/SD (168)]. The dibenzofuran concentration exceeded the HAET (540 ug/kg) in sediments collected from the Michigan SD (E2,000 ug/kg) and Fox S. CSO/SD (1,900 ug/kg) in Section B. In addition, dibenzofuran was correlated with HPAH ($r=0.80$) and LPAH ($r=0.84$) in the offshore sediments (PTI and Tetra Tech 1988). Dibenzofuran also correlated with PAH in the offshore sediments of Commencement Bay (Tetra Tech 1986a), suggesting that dibenzofuran and PAH had similar sources.

1,1'-Biphenyl was only found in the Fox S. CSO/SD (116). It was identified as a problem chemical because the concentration (E740 ug/kg) exceeded the HAET (270 ug/kg). In the past, biphenyl was used primarily in heat-transfer fluids (Kirk-Othmer 1985). Biphenyl is also found in oils, petroleum products, organic synthesizers, disease control agents for plants, and dyes for polyester materials (Tetra Tech 1986a; see Appendix H). No specific sources of biphenyl have been identified in the Fox S. CSO/SD (116) basin. However, because it is commonly associated with petroleum products, biphenyl contamination and PAH contamination were probably caused by similar sources.

Phthalates were identified as problem chemicals in the Michigan SD (total phthalates), Fox S. CSO/SD (116) (di-n-octyl phthalate and total phthalates), and the Michigan CSO (butyl benzyl phthalate and total phthalates). Di-n-octyl phthalate was the most abundant phthalate in both the Fox S. CSO/SD (116) (MH1=8,800 ug/kg) and the Michigan SD (Z3,600 ug/kg). However, di-n-octyl phthalate exceeded the 90th percentile concentration only in the Fox S. CSO/SD (116). Phthalates were not identified as problem chemicals in the two upstream manholes on the Fox S. CSO/SD (116), which indicates that phthalate contamination in this drain originated in the lower basin, downstream of MH2 and MH3. Butyl benzyl phthalate was the principal phthalate component of the sediment from the Michigan CSO (W039) (E3,300 ug/kg). Uses of phthalates are presented in Appendix H. No specific sources of phthalates have been documented for these three drains. However, because of their widespread use, there are probably multiple sources of phthalates.

Phenolic compounds were identified as problem chemicals in the Michigan SD, Michigan CSO (W039), and Fox S. CSO/SD (116). The concentration of 4-methylphenol exceeded the HAET (1,200 ug/kg) in the Michigan CSO (E16,000 ug/kg) and the Fox S. CSO/SD (MH1=E1,600 ug/kg, MH3=E9,300 ug/kg). Uses of 4-Methylphenol are summarized in Appendix H. No specific sources of 4-methylphenol have been identified in the Michigan CSO (W039) or Fox S. CSO/SD (116) basins. Detailed investigation of the operations in the basin is required to identify contaminant sources for these two drains.

2-Methylphenol (E110 ug/kg) and 2,4-dimethylphenol (E47 ug/kg) were identified as problem chemicals in the Michigan SD sediment sample based on exceedances of HAET. 2-Methylphenol has been associated with wood wastes and is commonly found in pulp mill effluents (Tetra Tech 1986a). Uses of 2-methylphenol are presented in Appendix H. No wood product-related industries have been identified in the Michigan SD basin. 2,4-Dimethylphenol is used as an antioxidant in rubber products. 2,4-Dimethylphenol is also a constituent in the manufacture of disinfectants, solvents, pharmaceuticals, insecticides, fungicides, plasticizers, polyphenylene oxide, wetting agents, and dyestuffs (Kirk-Othmer 1985). 2,4-Dimethylphenol was only detected in the sediment collected from the Michigan SD. However, the analytical detection limit exceeded the HAET (29 ug/kg) in 59 percent of the other drains sampled. Therefore, there may be other exceedances of HAET in the project area. Because it is used in petroleum products, 2,4-dimethylphenol contamination may be associated with PAH contaminant sources. However, further analyses are required to establish a correlation between PAH and 2,4-dimethylphenol.

Total chlorinated benzenes (E6,000 ug/kg), 1,4-dichlorobenzene (E4,800 ug/kg), and 1,2-dichlorobenzene (E1,200 ug/kg) were identified as problem chemicals in the sediment collected from the Michigan CSO based on exceedances of HAET. The concentration of 1,2-dichlorobenzene was the highest reported in the Elliott Bay Action Program project area. Because the Michigan CSO (W039) serves a primarily industrial area, there are numerous potential sources of solvents in the service drainage area (see Table 4-14).

Chlorinated benzenes were not detected in most drains in the study. The analytical detection limits for chlorinated benzenes exceeded the HAET in 43 percent of the samples. Uses of chlorobenzene are presented in Appendix H.

The concentrations of PCBs in the Michigan CSO (W039) sediment exceeded HAET (see Figure 4-29). The PCB concentration in the Michigan CSO (W039) was the third highest measured in the project area and was 1-2 orders of magnitude greater than the concentrations measured in the remaining drains. PCBs are no longer manufactured in the U.S. No specific sources of PCBs have been documented in the Michigan CSO (W039) service area. However,

because they were used extensively in the past, there were probably multiple historical sources of PCB contamination in the Michigan CSO (W039) service drainage area.

Other organic compounds that were identified as problem chemicals in the Michigan CSO (W039) include p,p'-DDT (E596 ug/kg) and p,p'-DDE (E356 ug/kg) and total xylenes (E160 ug/kg). Uses of p,p'-DDT and p,p'-DDE are summarized in Appendix H. p,p'-DDT and p,p'-DDE contamination in the Michigan CSO was probably due to historical use of these insecticides.

The concentration of xylenes in the Michigan CSO (W039) (E160 ug/kg) was the second highest concentration in the Elliott Bay Action Program project area [E187 ug/kg of xylene was detected in the Lander CSO/SD (105)]. Uses of xylenes are provided in Appendix H. No specific sources of xylenes have been documented in the Michigan CSO (W039) service drainage area. Xylene contamination could be associated with gasoline spills or improper disposal of solvents. Although several facilities in the service area have been identified as using solvents (see Table 4-14), it is not known whether xylenes are the specific solvents being used.

Other volatile organic compounds (i.e., vinyl chloride, 1,1-dichloroethane, and trans-1,2-dichloroethene) were identified as problem chemicals in the Fox S. CSO/SD (116). Vinyl chloride (E91 ug/kg) was identified as a problem chemical, because the concentration was the highest reported in the project area and exceeded the concentration measured in all other drains by 1-2 orders of magnitude. Vinyl chloride is a precursor to polyvinyl chloride and is used in a variety of polymers (see Appendix H). In addition, vinyl chloride is also used in electrical wire insulation, cables and piping, and in solvents. Vinyl chloride was historically used as a refrigerant in cooling equipment and as an aerosol propellant in some cosmetics, drugs, and pesticides until 1973 (Kirk-Othmer 1985). Polymers of vinyl chloride are important industrial chemicals because of their low cost and flame-retardant properties. There are no documented sources of vinyl chloride in the Fox S. CSO/SD (116) basin. However, because its concentration in the drain sediments was substantially higher than in other drains, there was likely a specific point source of vinyl chloride in the basin.

The source was probably in the upper portion of the basin because vinyl chloride was detected only in the farthest upstream manhole (MH3).

1,1-Dichloroethane is an intermediate in the production of vinyl chloride and 1,1,1-trichloroethane, in industrialized solvents, cleaning and degreasing agents, fumigants, and cutting fluids. The presence of 1,1-dichloroethane in the Fox S. CSO/SD (116) may have been related to the vinyl chloride contamination. Trans-1,2-dichloroethene is an intermediate in the production of other chlorinated ethenes (Kirk-Othmer 1985). These two compounds were only detected in the most upstream manhole (MH3) on the Fox S. CSO/SD (116). Therefore, the source of these contaminants probably originates in the upper basin, upstream of MH3 and Fox S. (see Map 3 in Map Appendix).

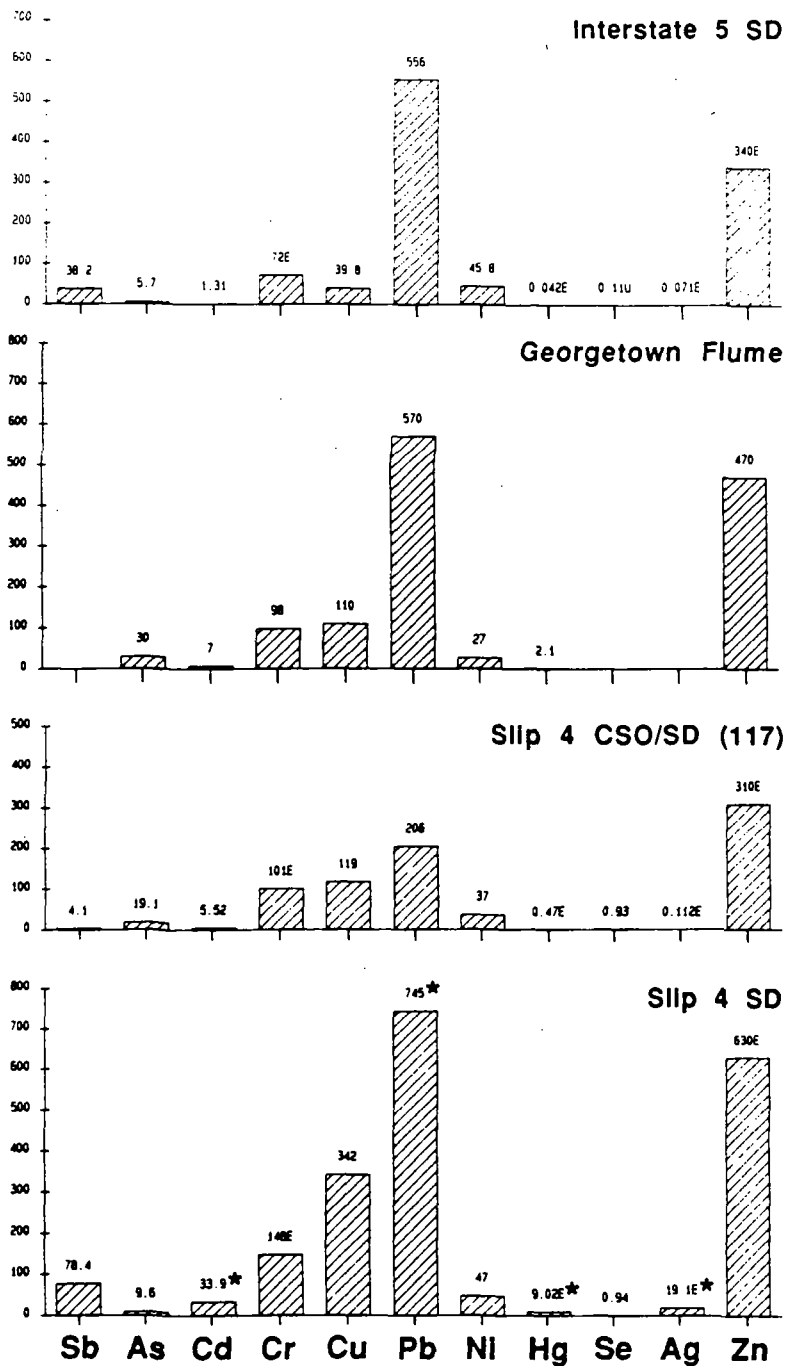
Section C--

Sediment samples were collected from three [I-5 SD, Slip 4 SD, Slip 4 CSO/SD (117)] of the five drains that discharge into the head of Slip 4 (see Figure 4-24). Results of the sediment sampling in Georgetown Flume (RL-01), conducted by Metro (Sample, T., 23 October 1987, personal communication) are included in the inter-basin comparisons. No data are available for the East Marginal pump station overflow (W043), which functions as an emergency overflow in the event of a pump failure.

Metals--Results from the metals analyses of these drain sediments are summarized in Figure 4-30. Cadmium, lead, mercury, and silver concentrations exceeded HAET only in the sediment sample collected from the Slip 4 CSO/SD (117). No metals exceeded HAET or 90th percentile concentrations in any of the other drains discharging into Slip 4.

The relative distribution of metals in the sediments from the Slip 4 drains is summarized in Table 4-15. With the exception of cadmium and silver in the Slip 4 CSO/SD (117) sediments, the relative distribution of metals and the individual metal concentrations in the drain sediments was within the range observed for urban street dust (Galvin and Moore 1982). This indicates that metals concentrations in the sediments collected from

CONCENTRATION (mg/kg dry weight)



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-30. Concentrations of metals in sediments collected from drains discharging into the Duwamish River Section C (Slip 4).

TABLE 4-15. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS
FROM DRAINS DISCHARGING INTO UPPER DUWAMISH ESTUARY, SECTION C

Metals	Georgetown Flume	I-5 SD	Slip 4 SD	Slip 4 CSO/SD (117)	Street Dust ^a
Antimony	NA ^b	3	<1	4	<1
Arsenic	2	<1	2	<1	1-5
Cadmium	<1	<1	<1	2	<1
Chromium	7	7	13	7	2-15
Copper	8	4	15	17	4-12
Lead	43	51	26	36	30-64
Mercury	<1	<1	<1	<1	<1
Nickel	2	4	5	2	2-4
Silver	NA	<1	<1	1	<1
Zinc	36	31	39	31	14-54
Total metals (mg/kg)	1,300 ^c	1,100 ^c	800 ^c	2,100 ^c	680-1,800 ^d

^a Commercial and industrial sites (Galvin and Moore 1982).

^b NA = Not analyzed.

^c Values reported as dry-weight concentrations.

^d Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

the Georgetown Flume, I-5 SD, and the Slip 4 SD were mainly from nonpoint sources such as urban runoff. The relative abundance of lead in the I-5 SD (51 percent) was greater than the relative abundance observed in the other drains in Slip 4 (26-43 percent). This slightly greater relative abundance may have been due to the predominance of highway runoff in the I-5 SD. The primary sources of lead in highway runoff are leaded gasoline, motor oil, transmission fluid, and babbitt-metal bearings (Krenkel and Novotny 1980).

HAET exceedances for cadmium, lead, mercury, and silver concentrations in Slip 4 CSO/SD (117) sediments suggest the presence of anthropogenic sources, particularly for cadmium and silver, which exhibited the highest concentrations measured during the source sampling effort, 33.9 mg/kg and 19.1 mg/kg, respectively (see Figure 4-30). Slip 4 CSO/SD (117) was one of the few drains sampled during the study where cadmium and silver constituted more than 1 percent of the total metals (the sum of antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) analyzed in the sediments.

The Slip 4 CSO/SD (117) serves the north end of the King County Airport and portions of Boeing property. Potential uses of cadmium, lead, silver, and mercury have been described earlier and are presented in Appendix H. Specific sources of these metals have not been documented in the Slip 4 CSO/SD (117) basin. However, because of the heavy industrial activity in the basin, it is likely that there are numerous historical and ongoing sources in the basin. Potential problems that have been identified include the storage of old batteries in an open, uncontained area at the King County Airport (Ecology 1987), and JP4 jet fuel storage tanks (which are a potential source of lead) on north Boeing Field (WEC Alert! 1987).

Organic Compounds--The organic compounds that were detected most frequently in the drains discharging into the upper Duwamish estuary, Section C, are summarized in Figure 4-31. PAH, PCBs, pesticides, and phenols have been identified as problem chemicals in the drains in Section C:

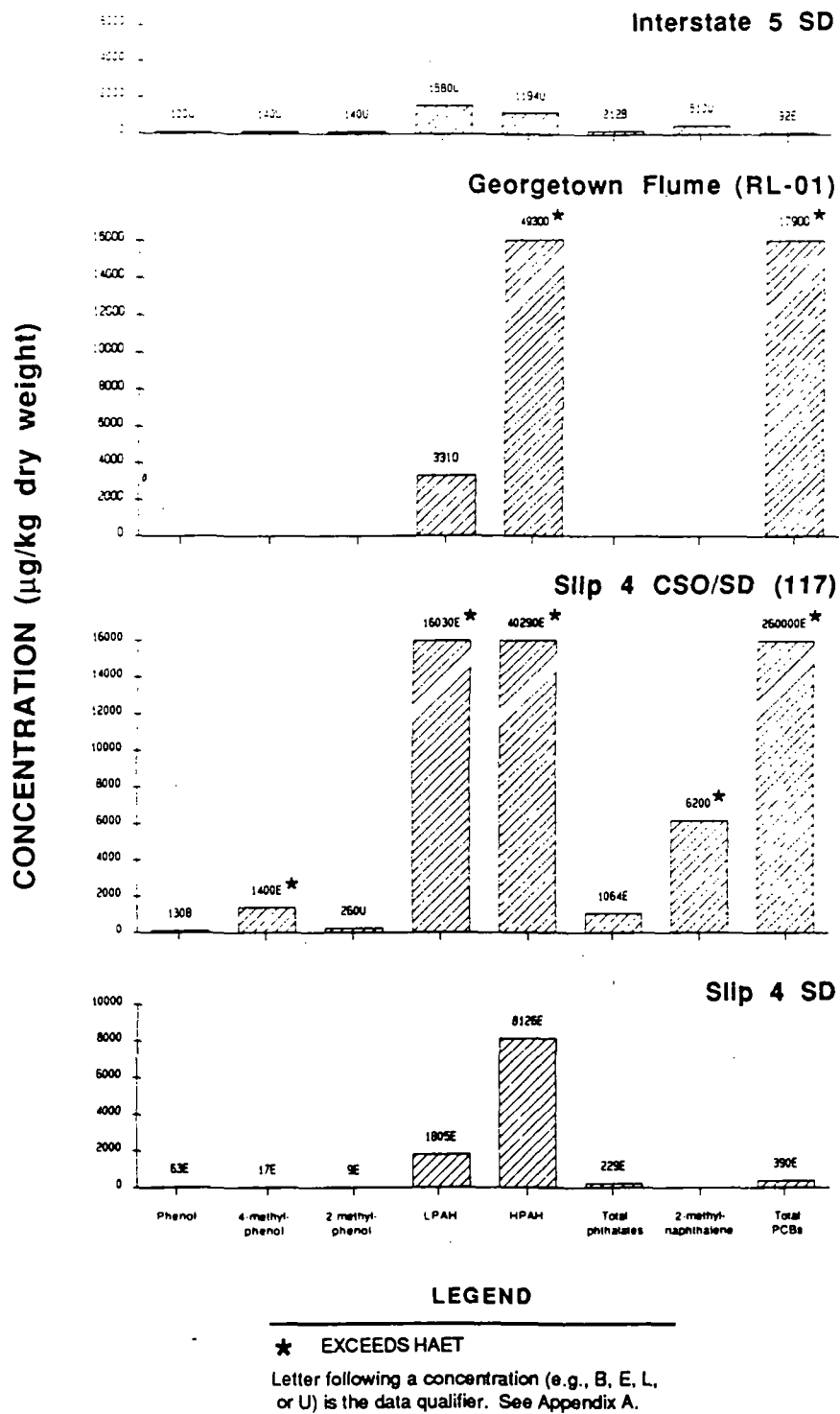


Figure 4-31. Concentrations of selected organic compounds in sediments collected from drains discharging into the Upper Duwamish Estuary, Section C.

- Slip 4 CSO/SD (117) - naphthalene, fluorene, phenanthrene, fluoranthene, indeno(1,2,3-c,d)pyrene, LPAH, HPAH, 2-methylnaphthalene, 4-methylphenol, p,p'-DDE, p,p'-DDT, and PCBs
- Georgetown Flume (RL-01) - fluorene, benzo(a)anthracene, chrysene, benzofluoranthenes, indeno(1,2,3-c,d)pyrene, HPAH, and PCBs (Sample, T., 23 October 1987, personal communication).

There were no organic compounds that exceeded HAET or the 90th percentile concentrations in the I-5 SD or the Slip 4 SD.

PAH and PCBs were the primary organic constituents in the Georgetown Flume and Slip 4 CSO/SD (117). The ratio of HPAH to LPAH in the drain sediments was variable:

	<u>HPAH/LPAH</u>
I-5 SD	0
Slip 4 SD	4.5
Slip 4 CSO/SD	2.6
Georgetown Flume	15

HPAH/LPAH ratios in the I-5 SD, Slip 4 SD, and Slip 4 CSO/SD (117) were relatively low compared to Georgetown Flume. The relative proportion of HPAH to LPAH has been used as an indicator of the ultimate source of PAH. Prahl and Carpenter (1983) reported that combustion fuel sources contain a higher proportion of HPAH than noncombusted fuel sources. It appears that the PAH in the Georgetown Flume had a larger contribution from combustion sources than the other drains in Section C.

The relative distributions of individual PAH compounds in Section C drain sediments are shown in Table 4-16. The relative distributions of PAH in the I-5 SD and Slip 4 SD were similar to the relative distributions in urban street dust. In addition, the total PAH concentrations in I-5 SD (E56 ug/kg) and Slip 4 SD (E9,920 ug/kg) sediments were within or lower than the range reported in urban street dust (1,420-11,730 ug/kg). Therefore, PAH in these drains was probably contributed largely from urban runoff. The

TABLE 4-16. RELATIVE PERCENT DISTRIBUTION OF PAH IN SEDIMENTS FROM DRAINS DISCHARGING INTO THE UPPER DUWAMISH ESTUARY, SECTION C (SLIP 4)

PAH	I-5 SD	Slip 4 SD	Slip 4 CSO/SD (117)	Georgetown Flume (RL01)	Street Dust ^a	Street Dust ^b
LPAH						
Naphthalene	<1	7	19	8	0	0
Acenaphthylene	<1	<1	<1	<1	0	0
Acenaphthene	<1	6	<1	10	0	0-7
Fluorene	<1	9	31	36	0	0-7
Phenanthrene	89	67	46	16	100	68-100
Anthracene	11	11	4	30	0	0-18
Total LPAH (ug/kg)	56 ^c	1,800 ^c	15,790 ^c	3,310 ^c	1,200-2,600 ^d	640-3,400 ^d
HPAH						
Fluoranthene	ND ^e	20	25	24	26-48	24-100
Pyrene	ND	15	21	<1	26-52	0-52
Benzo(a)anthracene	ND	10	6	11	0-12	0
Chrysene	ND	9	14	16	0-19	0-23
Benzo(b)fluoranthene	ND	9	7	8	0	0
Benzo(k)fluoranthene	ND	6	9	15	0-16	0-24
Benzo(a)pyrene	ND	7	7	11	0-9	0-13
Indeno(1,2,3-c,d)pyrene	ND	<1	5	7	0	0
Dibenzo(a,h)anthracene	ND	<1	<1	2	0	0
Benzo(g,h,i)perylene	ND	26	5	5	0	0
Total HPAH (ug/kg)	ND	8,120 ^c	40,290 ^c	49,300 ^c	3,100-9,480 ^d	780-9,480 ^d

^a Commercial and industrial sites (Galvin and Moore 1982).

^b All sites - residential, commercial, and industrial (Galvin and Moore 1982).

^c Values reported as dry-weight concentrations.

^d Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

^e ND = Not detected.

Slip 4 CSO/SD (117) and Georgetown Flume contained higher proportions of fluorene (31-36 percent) than the street dust samples, which suggests that there may have been sources other than urban runoff contributing to the LPAH in these two drains. In addition, the total LPAH concentration in Slip 4 CSO/SD (117) sediment (E15,790 ug/kg) was approximately 5-60 times greater than the LPAH concentration reported in street dust. Total LPAH concentration in the Georgetown Flume sediment sample (E3,310 ug/kg) was within the range of urban street dust (280-3,400 ug/kg).

With the exception of pyrene, the relative distributions of HPAH compounds in the Slip 4 CSO/SD (117) and Georgetown Flume were similar to the relative distribution of HPAH in street dust. The Georgetown Flume sediments contained a relatively smaller percentage of pyrene (<1 percent). However, the concentrations of HPAH in the flume (49,300 ug/kg) and Slip 4 CSO/SD (117) (40,290 ug/kg) were about 5-60 times greater than the HPAH concentrations reported in street dust (780-8,330 ug/kg). Therefore, there may have been sources other than urban runoff contributing to the HPAH contamination in these two drains.

The Slip 4 CSO/SD (117) and the Georgetown Flume both serve the north King County Airport area. The Slip 4 CSO/SD (117) serves approximately 150 ac on the north end of the King County Airport (see Map 3 in Map Appendix). The Georgetown Flume was originally installed to discharge cooling water from Seattle City Light's Georgetown steam plant. However, Seattle City Light identified numerous connections to the flume during their site inspections (Geissinger, L., 9 December 1987, personal communication). All side connections to the flume have recently been plugged. City Light plans to fill the flume to prevent future contamination problems (Geissinger, L., 9 December 1987, personal communication).

Two potential sources of PAH have been identified in the Slip 4 CSO/SD (117) basin: an airport maintenance yard, and an aircraft testing facility. Ecology inspected the maintenance yard in July 1986 and found several areas with evidence of past oil spills (Ecology 1987). Berms have reportedly been installed around the lubricating oil, diesel fuel, and solvent storage areas to contain future spills or leaks. The aircraft testing facility is

included on Ecology's list of hazardous waste sites (WEC Alert! 1987) as a high priority because of the suspected presence of PCBs and lead at the JP4 fuel storage area. There are probably other potential sources of PAH in the Slip 4 CSO/SD (117) basin because of the heavy industrial activity and use of petroleum products associated with the airport and its tenants.

Boeing removed contaminated sediments from the Slip 4 CSO/SD (117) system in 1985 (Smukowski, D., 14 December 1987, personal communication). After cleanup was completed, the Slip 4 CSO/SD (117) was diverted to the pump station on the Slip 4 SD system. The north end of the King County airport now drains to Slip 4 via the Slip 4 SD, and the Slip 4 CSO/SD (117) no longer exists.

Because the basin boundaries of the Georgetown Flume service drainage area are not well defined, it is difficult to identify potential contaminant sources in the basin. However, it is likely that the PAH contamination in the flume was related to the PCB contamination, as discussed below.

PCB concentrations exceeded HAET in the Georgetown Flume and Slip 4 CSO/SD (117) sediments (see Figure 4-30). PCB contamination in these two drains has been investigated by Metro, Seattle City Light, and Boeing. PCB contamination was initially found in the offshore sediments in Slip 4 during sampling conducted by U.S. EPA in 1982 and 1983 (U.S. EPA 1982, 1983), and by Metro in 1984 (Sample, T., 23 October 1987, personal communication). Metro traced the PCB contamination to two of the five drains [Georgetown Flume and Slip 4 CSO/SD (117)] that discharge into the head of Slip 4 (Sample 1987). Subsequent sampling conducted by Seattle City Light indicated that contamination in the flume was caused by past discharges from Seattle City Light's Georgetown steamplant facility (Raven Systems & Research 1988). PCB concentrations in sediments collected from the flume ranged from 2,500,000 ug/kg near the head of the flume to 7,900 ug/kg near the mouth of the flume (Raven Systems & Research 1988).

Soil contaminated with PCBs was found in a drainage pond on Seattle City Light's property that discharged to the flume. The pond received blowdown wastes from the steamplant's boiler system. PCB concentrations in the soils

from the pond ranged from 91,000,000 ug/kg in samples collected at depths of 1 ft to 7,700 ug/kg at depths of 4 ft (Raven Systems & Research 1988).

Sediment samples were not collected from the Georgetown Flume during the Elliott Bay Action Program because, at that time, the flume was being cleaned. However, samples were collected from the lift station on the Slip 4 SD, from a manhole on the I-5 storm drain, and from the last downstream manhole on Slip 4 CSO/SD (117). The results are consistent with the Metro data and show relatively low concentrations of PCBs (ug/kg) in the two storm drains, but substantial contamination in the CSO/SD:

	Metro (5/16/84)	Elliott Bay Action Program (10/3-7/85)
Slip 4 CSO/SD (117)	103,000	260,000
Slip 4 SD	19,500	E390
I-5 SD	644	E275

The source of the PCB contamination in the Slip 4 CSO/SD (117) has not been identified. Metro and Boeing investigated the CSO/SD system, but were unable to locate a source (Smukowski, D., 14 December 1987, personal communication). It is believed that the PCB contamination was caused by illegal dumping of waste material. As was mentioned earlier, Boeing had the contaminated sediments removed from Slip 4 CSO/SD (117) in 1985, and diverted flow from the drain to the Slip 4 SD system. It is not known whether there are ongoing sources of PCB in the basin.

Other problem chemicals identified in the Slip 4 CSO/SD (117) include 4-methylphenol, p,p'-DDT, and p,p'-DDE (see Figure 4-30). Uses of 4-methylphenol are summarized in Appendix H. The source of 4-methylphenol in the Slip 4 CSO/SD basin is unknown. The concentrations of p,p'-DDT (X4,300 ug/kg) and p,p'-DDE (X3,400 ug/kg) in the Slip 4 CSO/SD (117) were the highest concentrations reported in the project area and were 10-1000 times greater than the concentrations measured in the other drains.

No specific sources of p,p'-DDT have been documented in the Slip 4 CSO/SD (117) basin. Because of its extensive use (see Appendix H), there are probably numerous historical sources of p,p'-DDT in the basin. However,

ongoing sources may still exist if facilities continue to use p,p'-DDT purchased prior to 1973.

Section D--

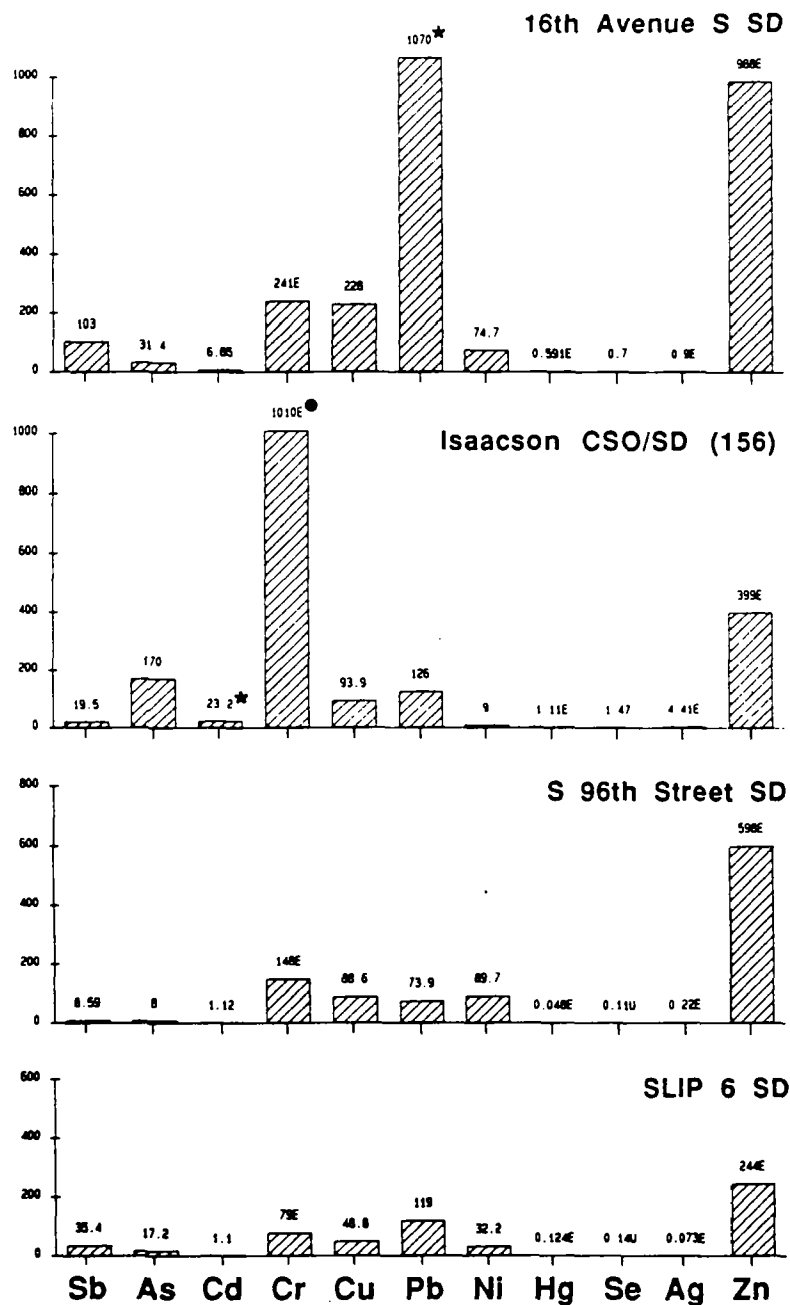
Sediment samples were collected from three storm drains (Slip 6 SD, S. 96th St. SD, 16th Ave. S. SD) and one CSO/SD [Isaacson CSO/SD (156)] that discharge into the Duwamish River upstream of Slip 4 (see Figure 4-24).

Metals--The results from the metals analyses of these drain sediments are summarized in Figure 4-32. No metals exceeded HAET or 90th percentile concentrations in the sediments collected from the Slip 6 SD or the S. 96th St. SD. Sediments from the Isaacson CSO/SD (156) exceeded the HAET for cadmium and the 90th percentile concentration for chromium. Lead exceeded the HAET in the sediment from the 16th Ave. S. SD.

The relative distributions of metals in the sediments from the drains in Section D are shown in Table 4-17. The relative distribution of metals in the Slip 6 SD sediments was within the range reported for street dust (Galvin and Moore 1982). In addition, with the exception of antimony, the concentrations of metals in the sediments were also within the ranges reported for street dust. The apparent discrepancy in antimony values may be caused by different analytical digestion procedures. As was explained earlier (see Section 3.2.4), antimony values were more affected by different digestion procedures than the other metals analyzed in the drain sediments. Therefore, the metals contamination observed in Slip 6 SD sediments was probably caused by nonpoint sources such as urban runoff.

No metals exceeded HAET or 90th percentile concentrations in the S. 96th St. SD sediments. However, the relative abundance of zinc (59 percent) in the sediments was greater than in any of the other drains sampled and exceeded the range for urban street dust (see Table 4-17), indicating that zinc may become a potential problem chemical in the S. 96th St. SD basin. Metro also identified zinc as a potential problem in the S. 96th SD (Sample, T., 13 November 1986, personal communication). On 13 May 1986, Metro collected sediment samples from six stations along the S. 96th SD

CONCENTRATION (mg/kg dry weight)



LEGEND

★ EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-32. Concentrations of metals in sediments collected from drains discharging into the Duwamish River, Section D.

TABLE 4-17. RELATIVE PERCENT DISTRIBUTION OF METALS IN SEDIMENTS FROM DRAINS DISCHARGING INTO THE UPPER DUWAMISH ESTUARY, SECTION D

Metals	Slip 6 SD	S. 96th St. SD	Isaacson CSO/SD (156)	16th Ave. S. SD	Street Dust ^a
Antimony	6	<1	1	4	<1
Arsenic	3	<1	9	1	1-5
Cadmium	<1	<1	1	<1	<1
Chromium	14	15	54	9	2-15
Copper	8	9	5	8	4-12
Lead	21	7	7	39	30-64
Mercury	<1	<1	<1	<1	<1
Nickel	6	9	<1	3	2-4
Silver	<1	<1	<1	<1	<1
Zinc	42	59	21	36	14-54
Total metals (mg/kg)	580 ^b	1,020 ^b	1,860 ^b	2,740 ^b	680-1,800 ^c

^a Commercial and industrial sites (Galvin and Moore 1982).

^b Values reported as dry-weight concentrations.

^c Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

system (see Figure 4-24). With the exception of Station VL01, all samples contained a high proportion of zinc (46-79 percent). Station VL01 was located immediately downstream of a chrome plating facility (Precision Engineering). Sediment collected at Station VL01 contained a greater abundance of chromium (56 percent, 365 mg/kg) than other stations sampled in the S. 96th SD (4-15 percent, 25-542 mg/kg). Precision Engineering is currently under investigation by Ecology, and has submitted a work plan to investigate soil and groundwater contamination on their property and contamination in the S. 96th SD below their property (Sweet-Edwards/EMCON 1988).

Ecology has identified two additional metal finishing operations in the basin that are potential sources of zinc (Cargill, D., 25 February 1988, personal communication). Only one of these facilities (Advance Electroplating) is currently permitted under Metro's industrial pretreatment program or Ecology's NPDES program. Advance Electroplating began discharging wastewater from their chrome and zinc plating facility to the sanitary sewer system in 1982. Prior to 1982, Advance Electroplating had a NPDES permit to discharge wastes into the S. 96th SD. Two samples of effluent from Adams Electroplating collected on 23 July 1981 by Ecology indicate that discharges from this facility contained elevated concentrations of several metals: <0.01-0.82 mg/L cadmium, 0.26-1.7 mg/L chromium, 1.2-1.3 mg/L copper, <0.02-0.66 mg/L lead, 0.84-5.9 mg/L nickel, and 3.2-5.7 mg/L zinc (Ecology and Environment 1986). However, Ecology and Environment (1986) reported that the ditch along S. 96th St. has been filled and, therefore, contamination from past discharges does not pose a serious threat to human health or the environment if the buried sediments are not disturbed. Advanced Electroplating is included in U.S. EPA's CERCLIS (U.S. EPA, 22 October 1987, personal communication).

The other metal plating facility, Advance Hard Chrome, Inc./Repair Technology, Inc. (400 S. 96th St.) operates a small chrome plating facility and machine shop. From 1971 through 1985, the facility was operated by Advance Electroplating. During that period, all process wastes from the facility were sent to Advance Electroplating (9585 8th Ave. S.) for disposal (Ecology and Environment 1986). Ecology and Environment (1986) inspected

Advance Hard Chrome, Inc. and found no evidence of historic or ongoing waste disposal problems at the site.

Metals contamination (i.e., copper, lead, nickel, and zinc) was found in soil samples from the S. 96th St. SD basin during excavation conducted as part of the Renton Effluent Transfer Program (Cargill, D., 25 February 1988, personal communication). The S. 96th St. SD is included on Ecology's hazardous waste site list as a high priority because of metals contamination (WEC Alert! 1987). Also, during the Elliott Bay Action Program source sampling program, an employee of a company located near the mouth of the S. 96th St. SD informed sampling personnel that discharges in the drain frequently changed colors at certain times of the day, particularly at night. However, there is currently insufficient information available to identify specific contaminant sources in the basin.

Both cadmium and chromium have been identified as problem metals in the Isaacson CSO/SD (156) (see Figure 4-32). In addition to exceeding the 90th percentile concentration for chromium, the relative abundance of chromium in sediment from the Isaacson CSO/SD (156) (54 percent) was greater than in the other three drains sampled in Section D (9-15 percent) and exceeded the range reported in urban street dust (2-15 percent) (see Table 4-17). Also, Isaacson CSO/SD was one of the few drains sampled during the source investigation where the relative abundance of cadmium exceeded 1 percent.

Uses of both cadmium and chromium are presented in Appendix H. Based on the similarities in usage, the chromium and cadmium contamination in the Isaacson CSO/SD (156) may have been caused by the same sources. The Isaacson CSO/SD (156) serves portions of the King County Airport. Land use in the basin is exclusively industrial. No specific sources of cadmium and chromium have yet been documented in the basin.

Lead was the only problem chemical identified in the 16th Ave. S. SD (see Figure 4-32). The lead concentration in the sediment from the drain (1,070 mg/kg) did not exceed the range of concentrations reported in urban street dust (90-1,300 mg/kg; Galvin and Moore 1982). In addition, the

relative distribution of metals in the drain sediments was similar to the distribution of metals reported in street dust (see Table 4-17), which suggests that contamination may have been caused by nonpoint rather than specific contaminant sources in the basin. The drain serves the section of 16th Ave. S. between E. Marginal Way S. and the Duwamish River. The area surrounding 16th Ave. S. is heavily industrialized, but it is not known if there are any drain connections from this area into the 16th Ave. S. SD. The drain appears to serve only the 16th Ave. S. right-of-way.

Organic Compounds--The organic compounds detected most frequently in the drains discharging into Section D of the upper Duwamish estuary are summarized in Figure 4-33. PAH, phthalates, PCB, and benzoic acid were identified as problem chemicals in the following drains in Section D:

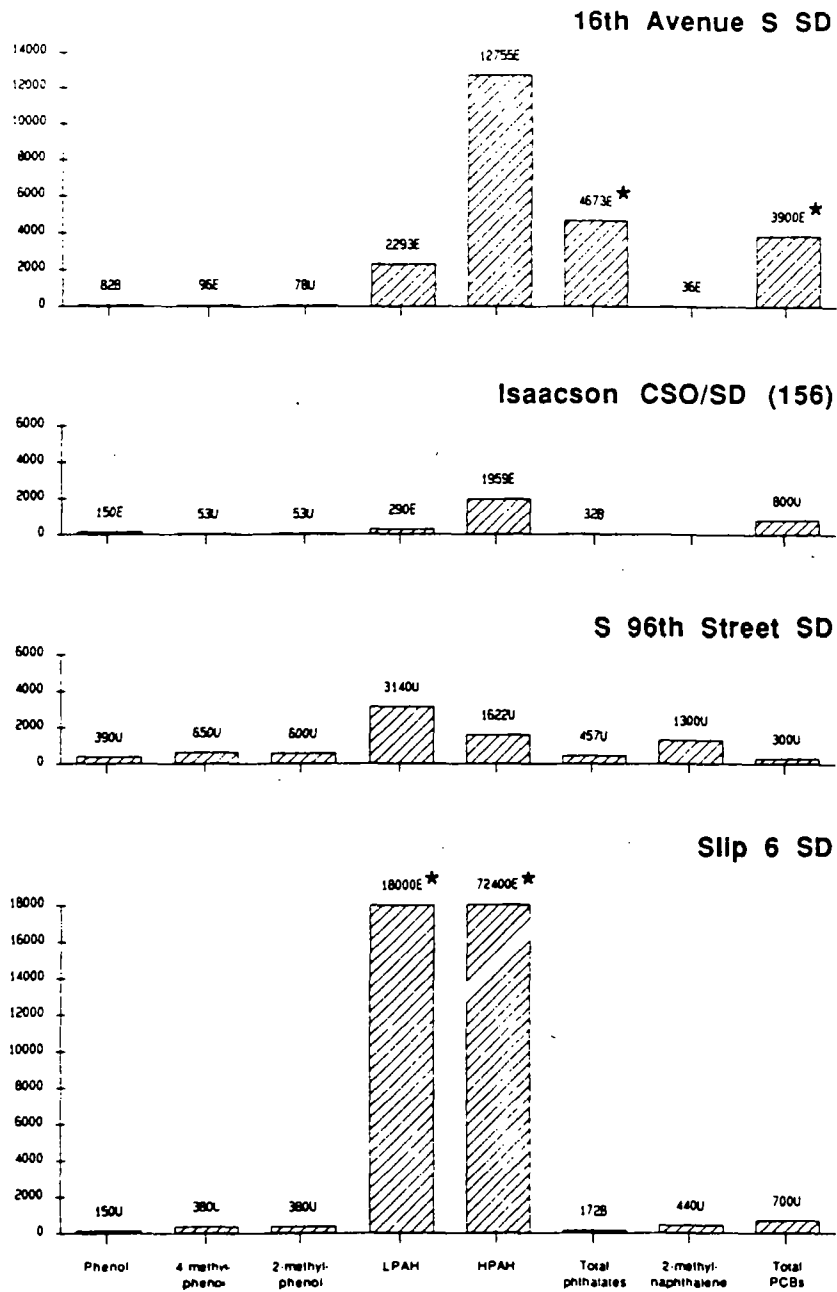
- 16th Ave. S. SD - di-methyl phthalate, total phthalates, PCBs, and benzoic acid
- Slip 6 SD - phenanthrene, fluoranthene, pyrene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-c,d)pyrene, LPAH, HPAH, and carbazole.

PAH compounds were the most abundant organic compounds found in the sediments collected from the Isaacson CSO/SD, 16th Ave. S. SD, and Slip 6 SD. PAH compounds were not detected in the S. 96th SD at detection limits of 79-1,200 ug/kg. Each of these detection limits was less than HAET, but the detection limits for acenaphthene and dibenzo(a,h)anthracene were equal to or greater than LAET concentrations. The ratio of HPAH to LPAH was similar in all three drains where PAH was detected, indicating similar PAH sources in the three basins:

	<u>HPAH/LPAH</u>
Isaacson CSO/SD	6.8
16th Ave. S. SD	5.5
Slip 6 SD	4.0

The methylphenanthrene (MP) to phenanthrene (P) ratio has been used to distinguish combusted fuel sources from noncombusted sources (Prah1 and

CONCENTRATION ($\mu\text{g/kg}$ dry weight)



LEGEND

★ EXCEEDS HAET

Letter following a concentration (e.g., B, E, L, or U) is the data qualifier. See Appendix A.

Figure 4-33. Concentrations of selected organic compounds in sediments collected from drains discharging into the Upper Duwamish Estuary, Section D.

Carpenter 1983). A value between 0.5 and 1.0 for MP/P is typical in combustion PAH mixtures, and a value between 2 and 6 is typical of noncombusted PAH mixtures. Methylphenanthrenes were only found in the Slip 6 SD sediment sample. The MP/P ratio for this drain was 0.13, which indicates that sources were primarily associated with combusted fuel products.

The relative percent distribution of individual PAH compounds in the sediments from the Slip 6 SD was within the ranges measured in urban street dust (Table 4-18). However, the total PAH concentration in Slip 6 SD (90,200 ug/kg) was 7-60 times greater than the PAH concentrations observed in street dust (1,420-12,800 ug/kg), indicating that there were sources other than urban runoff in the Slip 6 SD basin.

Potential PAH sources that have been identified in the Slip 6 SD basin include possible historical contamination from a petroleum distributor that operated in the basin in the 1940s (Sweet-Edwards & Associates and Harper-Owes 1985), and an aircraft manufacturer that is on U.S. EPA's CERCLIS (U.S. EPA, 22 October 1987, personal communication).

PAH contamination has been documented in the S. 96th SD. Benzo(a)pyrene was measured at a concentration of 800 mg/kg in soil excavated during the Renton Effluent Transfer Project. The state classified this soil as hazardous material (Cargill, D., 25 February 1988, personal communication).

Carbazole was identified as a problem chemical in the Slip 6 SD because the concentration in the sediment (E1,600 ug/kg) was the highest measured during the study, and was 4-90 times greater than the concentrations measured in any of the other drains. Carbazole is an important dye intermediate, and is used in making photographic plates that are sensitive to ultraviolet light (Windholz 1983; see also Appendix H). No dye-related facilities have been identified as potential sources in the basin. However, because it is a PAH, the carbazole contamination in this drain may have been associated with PAH sources.

Phthalates (total phthalates=E4,670 ug/kg; di-methyl phthalate=4,300 ug/kg) were also identified as problem chemicals in the Slip 6 SD

TABLE 4-18. RELATIVE PERCENT DISTRIBUTION OF PAH IN SEDIMENTS FROM DRAINS DISCHARGING INTO THE UPPER DUWAMISH ESTUARY, SECTION D

PAH	Isaacson CSO/SD (156)	596th SD	16th Ave. S. SD	Slip 6 SD	Street Dust ^a	Street Dust ^b
LPAH						
Naphthalene	<1	ND ^c	2	<1	0	0
Acenaphthylene	<1	ND	<1	<1	0	0
Acenaphthene	<1	ND	<1	5	0	0-7
Fluorene	<1	ND	5	7	0	0-7
Phenanthrene	93	ND	80	79	100	68-100
Anthracene	7	ND	13	8	0	0-18
Total LPAH (ug/kg)	193 ^d	--	2,120 ^d	17,780 ^d	1,200-2,600 ^e	640-3,400 ^e
HPAH						
Fluoranthene	14	ND ^f	28	21	26-48	24-100
Pyrene	17	ND	22	22	26-52	0-52
Benzo(a)anthracene	4	ND	6	5	0-12	0
Chrysene	11	ND	18	14	0-19	0-23
Benzo(b)fluoranthene	18	ND	6	5	0	0
Benzo(k)fluoranthene	19	ND	6	18	0-16	0-24
Benzo(a)pyrene	<1	ND	5	6	0-9	0-13
Indeno(1,2,3-c,d)pyrene	<1	ND	3	5	0	0
Dibenzo(a,h)anthracene	<1	ND	<1	<1	0	0
Benzo(g,h,i)perylene	7	ND	4	4	0	0
Total HPAH (ug/kg)	1,949 ^d	--	12,680 ^d	72,400 ^d	3,100-9,480 ^e	780-9,480 ^e

^a Commercial and industrial sites (Galvin and Moore 1982).

^b All sites - residential, commercial, industrial (Galvin and Moore 1982).

^c Not detected at concentrations of 300-1,200 ug/kg.

^d Values reported as dry-weight concentrations.

^e Street dust values reported in wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

^f Not detected at concentrations of 93-310 ug/kg.

(see Figure 4-33). Uses of phthalates are provided in Appendix H. No specific sources of phthalates have been documented in the Slip 6 SD basin. However, because of their widespread use, there may be multiple sources of phthalates. Because of their use in lubricating oils, the phthalate contamination in the drain may have been associated with the PAH sources.

Benzoic acid (E3,100 ug/kg) exceeded the HAET concentration (73 ug/kg) in the Slip 6 SD sediment sample. Uses of benzoic acid and its salts and esters are provided in Appendix H. No specific sources of benzoic acid have been documented in the Slip 6 SD basin. However, because it is used in similar products, benzoic acid contamination may have been associated with sources similar to those for carbazole or phthalates.

4.3.9 Alki Point/Duwamish Head

The 56th Ave. SW SD is the only drain in the Alki Point/Duwamish Head study area that was sampled during the Elliott Bay Action Program investigation (Figure 4-34). The 56th SW SD serves approximately 255 ac in West Seattle. Land use in the basin is primarily residential. The SW Fairmount SD, also located in this area, was investigated during the sampling program, but could not be sampled because of insufficient sediment deposits in the drain lines.

Metals--

The concentrations of metals and selected organic compounds measured in the sediments from the 56th Ave. SW SD are summarized in Figure 4-35. None of the metals in the drain sediment sample exceeded the HAET or the 90th percentile concentration. With the exception of chromium and nickel, the relative distribution of metals in the drain were within the ranges reported in residential street dust samples (Table 4-19). Chromium (35 percent), zinc (24 percent), and nickel (21 percent) were the most abundant metals in the sample. The concentration of individual metals in the 56th SW SD was generally less than the range reported in residential street dust samples (see Table 4-2). Therefore, metals in the sediments from the 56th Ave. SW SD were probably associated with nonpoint sources such as urban runoff.

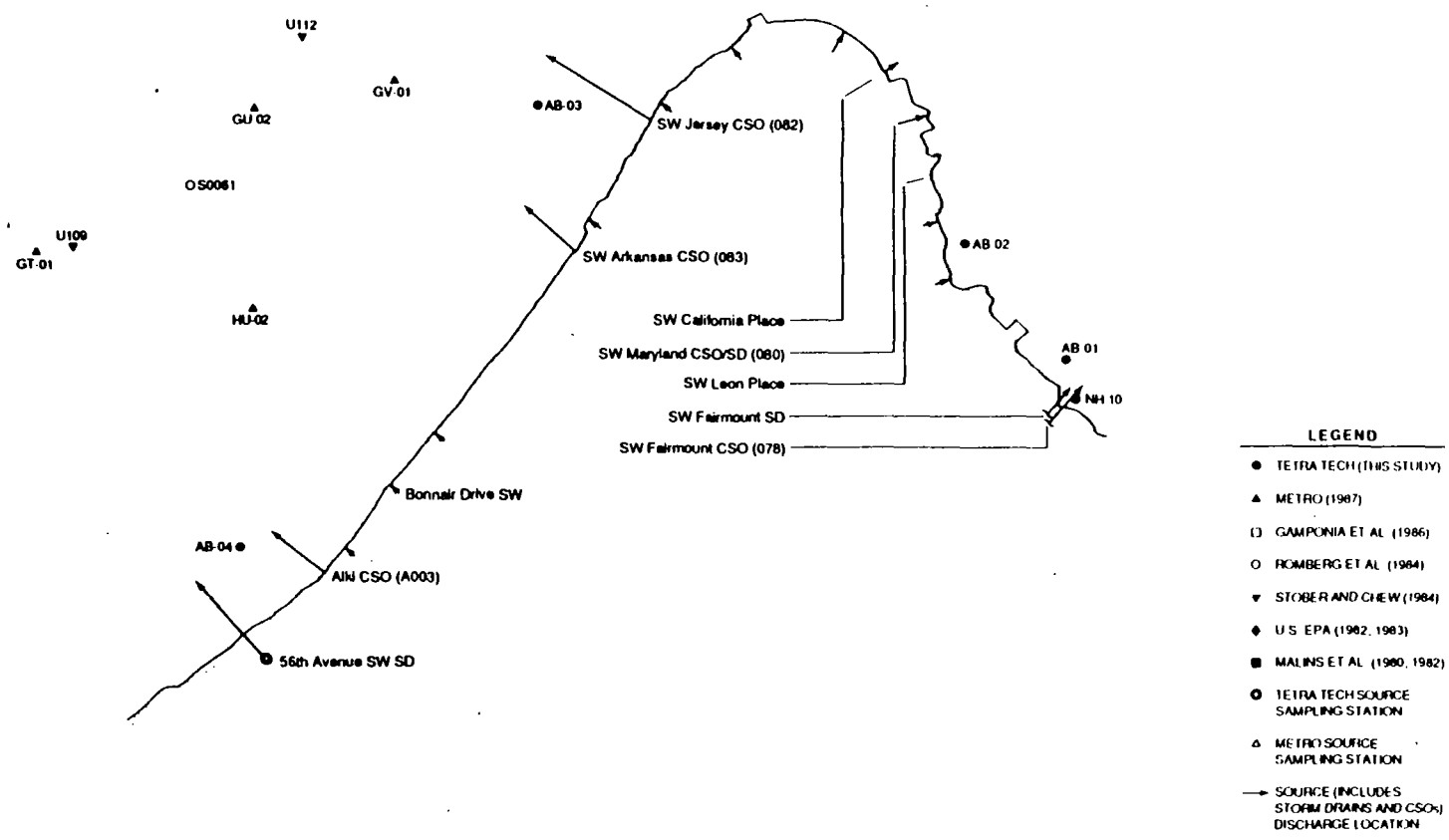
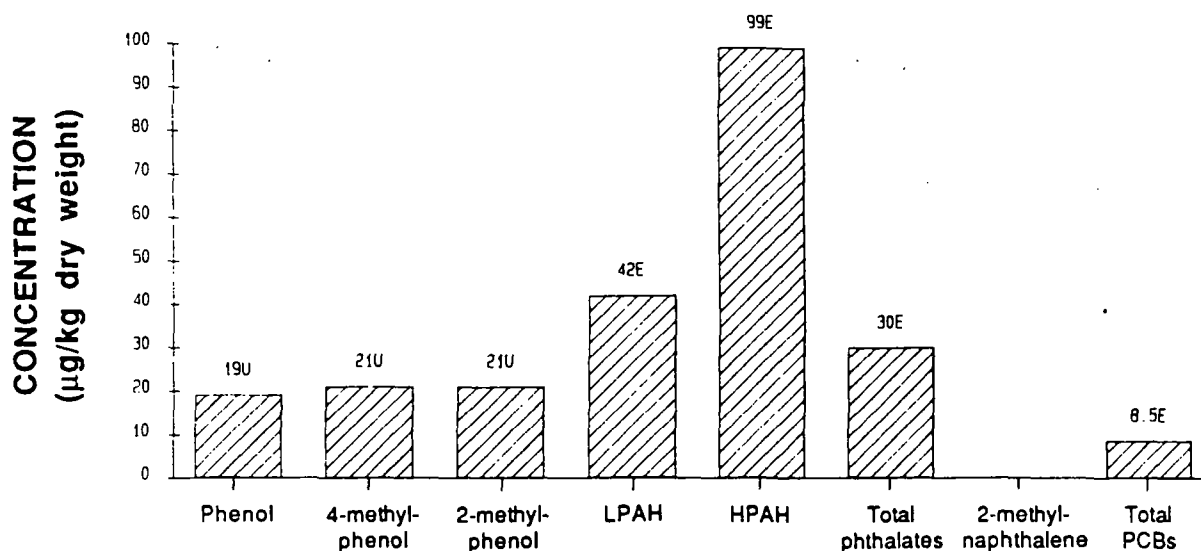
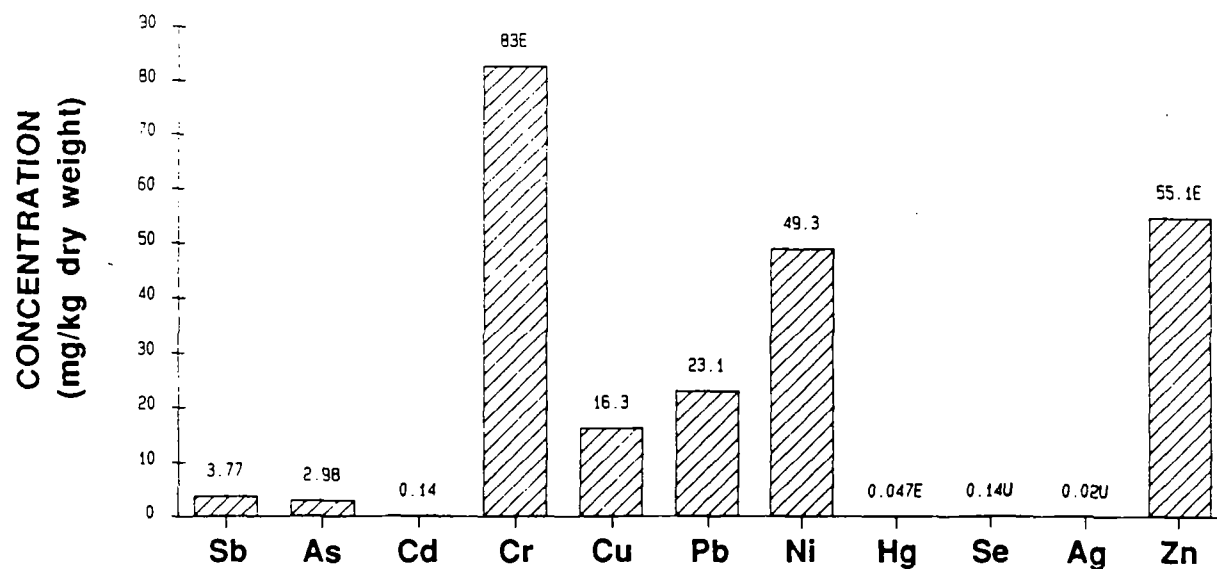


Figure 4-34. Locations of offshore and drain sampling stations, CSOs, and storm drains in the Duwamish Head/Aiki Beach study area.



LEGEND

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-35. Concentrations of metals and selected organic compounds in sediments collected from the 56th Avenue SW storm drain.

TABLE 4-19. RELATIVE PERCENT DISTRIBUTION
OF METALS IN 56TH Ave. SW SD

Metals	56th Ave. SW SD	Street Dust ^a
Antimony	2	<1
Arsenic	1	1-5
Cadmium	<1	<1
Chromium	35	2-24
Copper	7	3-29
Lead	10	10-77
Mercury	<1	<1
Nickel	21	2-5
Silver	<1	<1
Zinc	24	17-47
Total metals (mg/kg)	234 ^b	530-1,100 ^c

^a Residential sites (Galvin and Moore 1982).

^b Value reported as dry-weight concentration.

^c Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

Organic Compounds--

p,p'-DDT (E12.1 ug/kg) is the only organic compound that exceeded HAET (11 ug/kg) in the 56th Ave. SW SD basin (see Figure 4-35). The presence of p,p'-DDT in the drain sediments was probably related to historical use of p,p'-DDT in the basin (see Appendix H). However, there may be ongoing sources of p,p'-DDT if property owners continue to use p,p'-DDT purchased prior to 1973 when its use was restricted by U.S. EPA.

4.4 ADDITIONAL CSO AND STORM DRAIN RELATIONSHIPS TO POTENTIAL SOURCES IN THE BASIN

The results of the chemical analyses of sediments from different CSOs and storm drains are compared in the following sections. The data from samples collected from the seven drains that function only as CSOs during this investigation were compared to identify any similarities in the distributions of chemicals in the CSO sediment samples. Lead was identified most frequently as a problem chemical in the drain sediments. Elevated concentrations of lead in the project area may have been related to emissions from the lead smelter that operated on Harbor Island between 1937 and 1984. Lead concentrations from storm drains in the project area were compared to identify potential relationships between the concentration of lead in the drain sediments and the distance from the smelter. Finally, the metals results from two storm drains that serve shipyards, the Duwamish SD and Fox S. CSO/SD (116), were compared to determine if there were any similarities between drain sediments, sandblast grit, and offshore contamination.

4.4.1 CSO Comparisons

The following seven CSOs (six Metro and one city) were sampled during the Elliott Bay Action Program (see Figure 1-2):

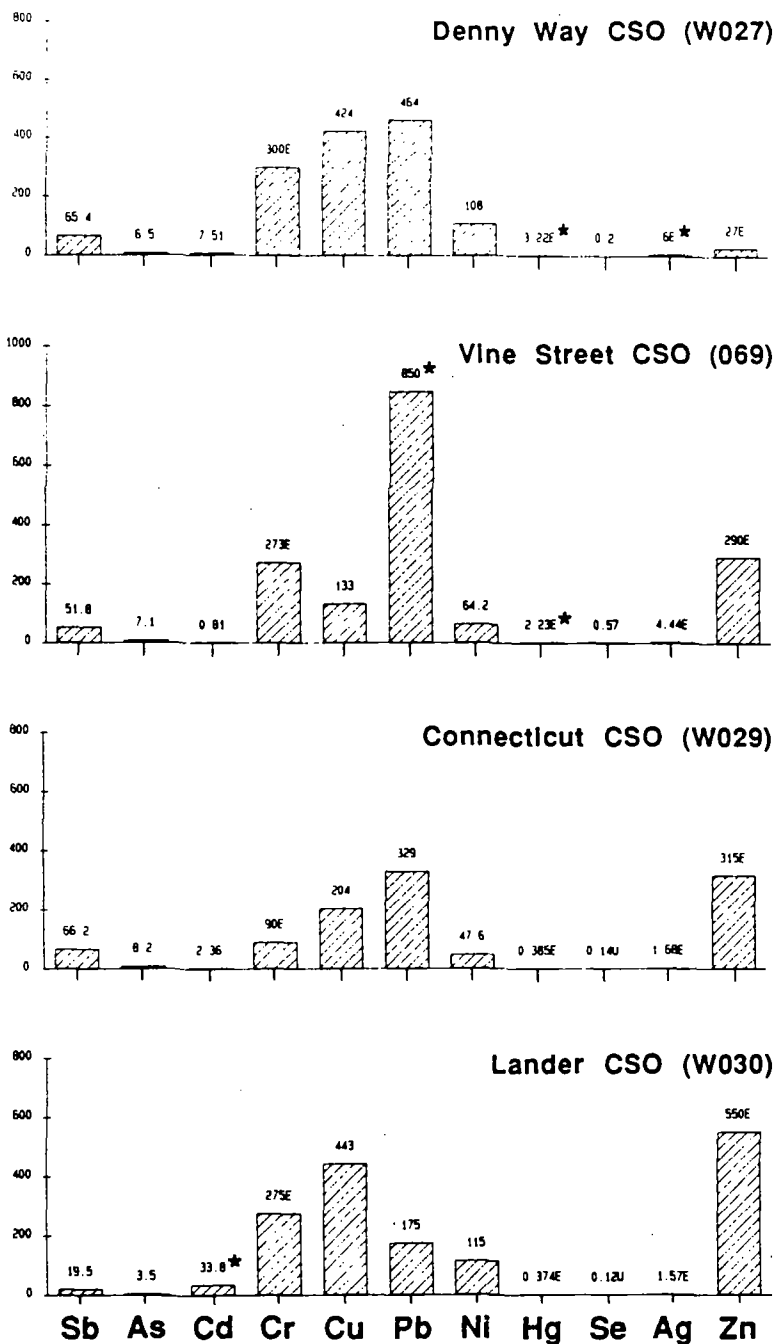
- Denny Way (W027)
- Vine (069)

- Connecticut (W029)
- Lander (W030)
- Hanford (W032)
- Michigan (W039)
- Brandon (W041).

The results of the chemical analyses indicate that although there were some similarities in the relative distribution of contaminants found in the CSO sediments, individual differences associated with specific land uses in each basin did occur. The results of the metals analyses are summarized in Figure 4-36. Chromium, copper, lead, and zinc comprised more than 90 percent of the metals (calculated as the sum of antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) in each drain. In most cases, the relative distribution of metals and the concentrations of individual metals were within the ranges reported for urban street dust. The concentration of silver in CSO sediments (1.57-6.0 mg/kg) was generally higher than the ranges reported in urban street dust (0.01-0.5 mg/kg; Galvin and Moore 1982).

CSOs that serve heavily industrialized areas (i.e., Michigan and Brandon CSOs) generally exhibited higher concentrations of metals. Metals concentrations in the Michigan and Brandon CSOs were 3,660 mg/kg and 5,200 mg/kg, respectively, compared to 1,410-2,200 mg/kg in the remaining CSOs. The service areas for most of these remaining CSOs contain a higher proportion of commercial areas than the Michigan and Brandon CSOs, which serve primarily industrial areas. The relatively high concentrations of metals in the Brandon and Michigan CSOs, and the exceedance of HAET for several metals in both CSOs suggests the presence of point sources. Metals that exceeded the HAET or 90th percentile concentration in each CSO are summarized below:

CONCENTRATION (mg/kg dry weight)



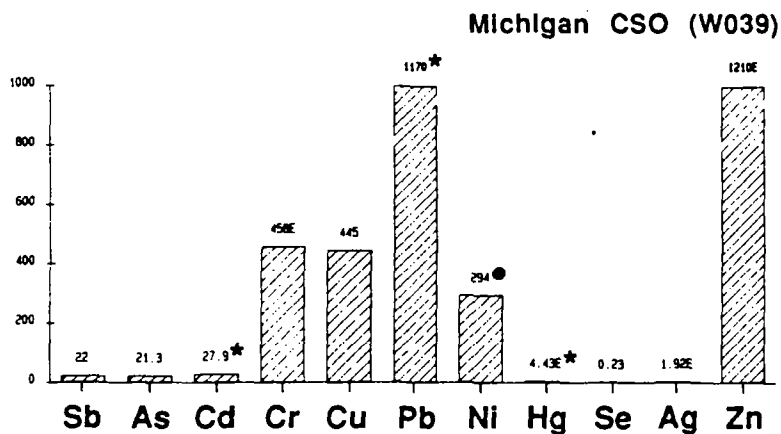
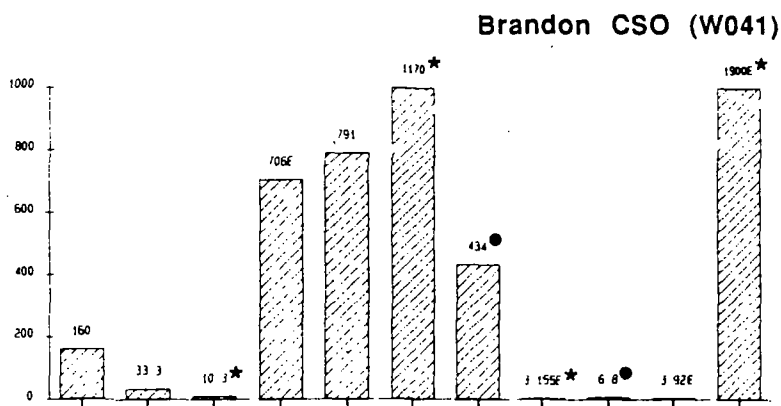
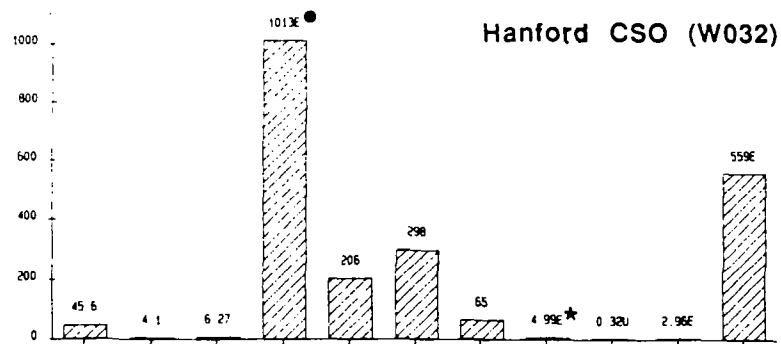
LEGEND

* EXCEEDS HAET

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-36. Concentrations of metals in sediments collected from CSOs.

CONCENTRATION (mg/kg dry weight)



LEGEND

EXCEEDS HAET

● EXCEEDS 90th PERCENTILE CONCENTRATION

Letter following a concentration (e.g., E or U) is the data qualifier. See Appendix A.

Figure 4-36. (Continued).

- Denny Way (W027) - mercury and silver
- Vine (069) - lead and mercury
- Connecticut (W029) - none
- Lander (W030) - cadmium
- Hanford (W032) - chromium and mercury
- Michigan (W039) - cadmium, lead, nickel, and mercury
- Brandon (W041) - cadmium, lead, nickel, selenium, mercury, and zinc.

The relative abundances of specific metals in the Denny Way CSO (i.e., zinc, chromium, and copper), Lander CSO (cadmium), and Hanford CSO (chromium) were outside the range reported for urban street dust (Table 4-20). The Denny Way CSO contained a relatively low proportion of zinc (2 percent) and higher proportions of chromium and copper (51 percent) compared with street dust (14-54 percent zinc, 6-27 percent copper and chromium). This difference suggests that there were sources other than urban runoff contributing to the copper and chromium concentrations in this CSO.

The sediment from the Lander CSO contained the highest concentration of cadmium measured during the study, and was one of the few drains sampled where cadmium constituted greater than 1 percent of the total metals in the drain sediments. The cadmium concentration in the sediment (33.8 mg/kg) was more than 10 times greater than the concentrations reported in urban street dust (0.6-2.0 mg/kg; Galvin and Moore 1982). The relatively high percentage of cadmium in the Lander CSO sediments is indicative of a specific point source and may have been related to metal platers and metal recyclers operating in the basin.

The relative abundance of chromium (46 percent) in the Hanford CSO was about three times greater than the highest relative abundance reported for

TABLE 4-20. RELATIVE PERCENT DISTRIBUTION OF METALS
IN CSO SEDIMENT SAMPLES

Metals	Denny Way (W027)	Vine (069)	Connecticut (W029)	Lander (W030)	Hanford (W032)	Michigan (W039)	Brandon (W041)	Street Dust ^a	Street Dust ^b
Antimony	5	3	6	1	2	<1	3	<1	<1
Arsenic	<1	<1	<1	<1	<1	<1	<1	1-5	1-5
Cadmium	<1	<1	<1	2	<1	<1	<1	<1	<1
Chromium	21	16	8	17	46	13	14	2-15	2-24
Copper	30	8	19	27	9	12	15	4-12	3-29
Lead	33	51	31	11	14	32	22	30-64	10-77
Mercury	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nickel	8	4	4	7	3	8	8	2-4	2-5
Silver	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zinc	2	17	30	34	25	33	36	14-54	14-54
Total metals (mg/kg)	1,410 ^c	1,680 ^c	1,060 ^c	1,620 ^c	2,200 ^c	3,660 ^c	5,200 ^c	680-1,800 ^d	530-1,800 ^d

^a Commercial and industrial sites (Galvin and Moore 1982).

^b All sites - residential, commercial, and industrial (Galvin and Moore 1982).

^c Values reported as dry-weight concentrations.

^d Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

urban street dust (2-15 percent), and was outside the range reported for all (residential, commercial, and industrial) street dust samples (2-24 percent). In addition, the concentration of chromium in the CSO sediment sample (E1,013 mg/kg) was 4-50 times greater than the concentrations reported in urban street dust (20-230 mg/kg) and exceeded the concentrations measured in other CSOs (E90-706 mg/kg). The large chromium component indicates that there were specific sources of chromium other than urban runoff in the Hanford CSO service drainage area.

Selected organic compounds measured in the CSO sediments are summarized in Figure 4-37. Fewer trends were apparent in the distribution of organic compounds in CSO sediments than were found with metals. As was the case with most drains sampled during the Elliott Bay Action Program study, PAH was the most frequently detected organic compound in the CSO sediments. PAH compounds are common contaminants found in samples of urban street dust (Galvin and Moore 1982) and atmospheric particulates in urban areas (Wakeman et al. 1980). Other organic compounds (e.g., phenols, PCBs, and phthalates) were identified as problem chemicals (i.e., concentration exceeded HAET or 90th percentile) within individual CSOs and were apparently related to specific sources. PAH compounds were the major organic constituents in the Denny Way CSO, Vine CSO, and Lander CSO. The concentrations of other organic compounds in these three CSOs were generally 2-3 orders of magnitude lower than the PAH concentration. PAH compounds were present in the remaining CSOs, but 4-methylphenol was the primary organic constituent in both the Brandon CSO and the Hanford CSO. 4-Methylphenol, PAHs, and PCBs were the major organic constituents in the Michigan CSO.

The concentration of HPAH was greater than the concentration of LPAH (HPAH/LPAH ratios ranged from 1.7-4.1) in the Vine, Michigan, Denny Way, Connecticut, and Brandon CSOs. This relationship was reversed in the Lander CSO and Hanford CSOs (HPAH/LPAH ratio of 0.71-0.90), which indicates that there may have been different sources of PAH in these two CSOs than in the others (Table 4-21). In general, a higher proportion of HPAH is indicative of combustion-related fuel sources and a predominance of LPAH compounds is indicative of noncombusted (i.e., spills and leaks) sources (Prah1 and Carpenter 1983).

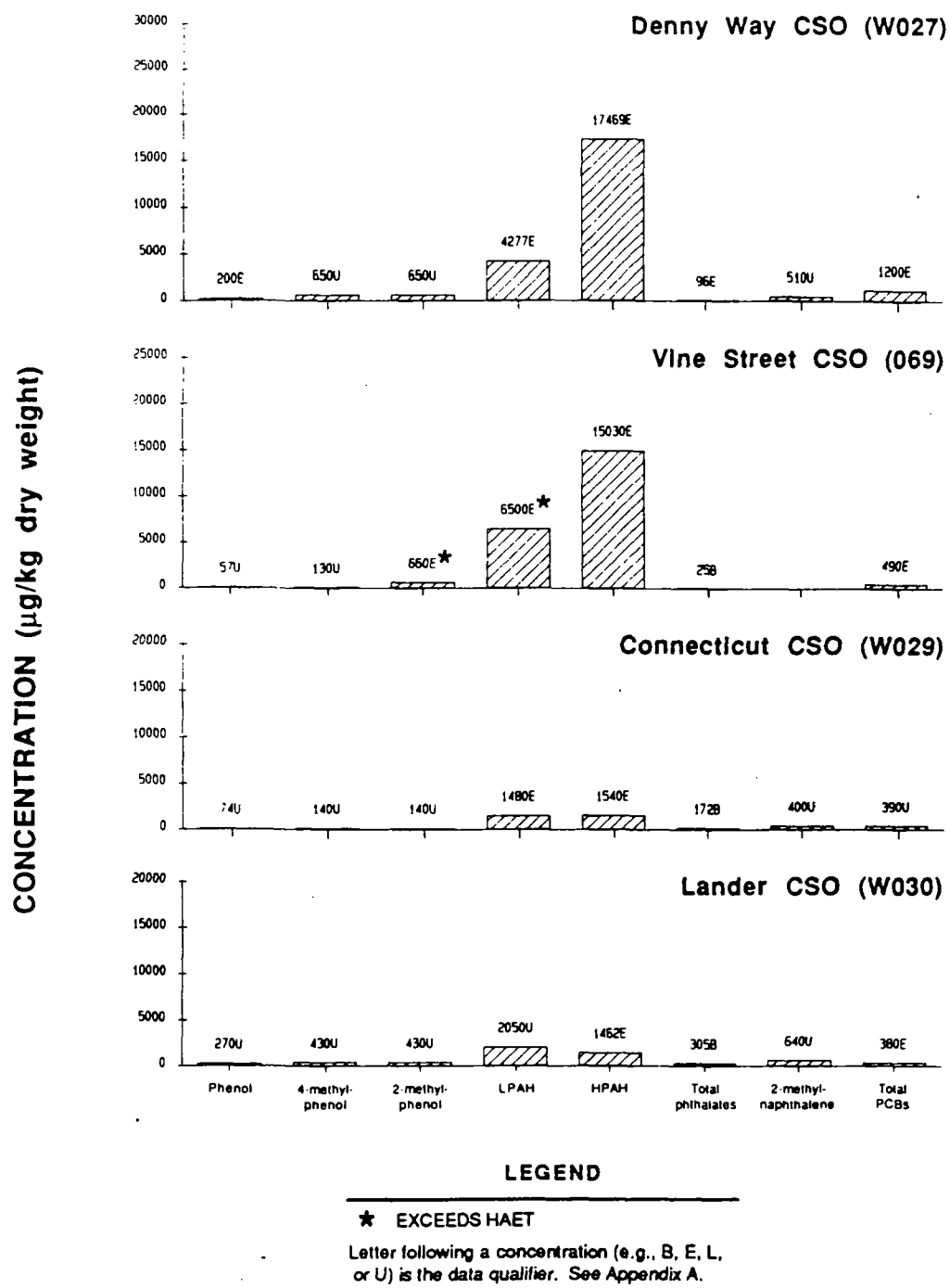
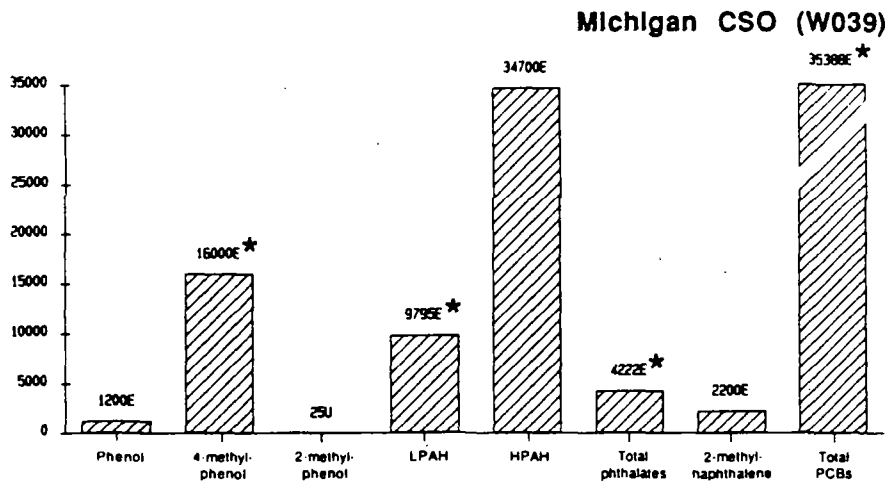
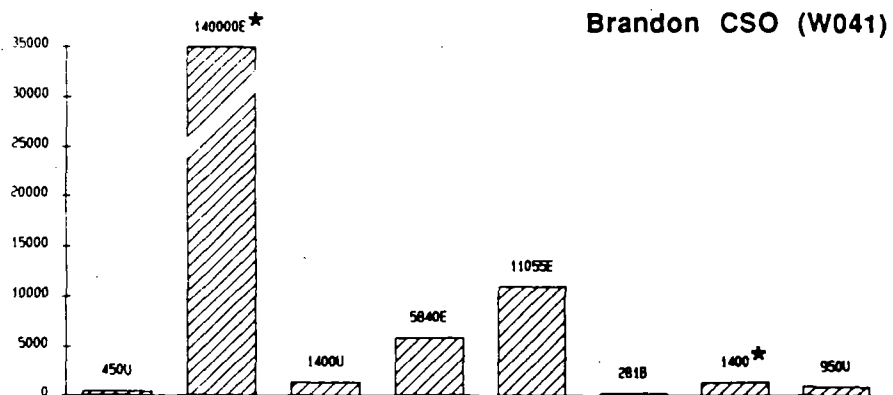
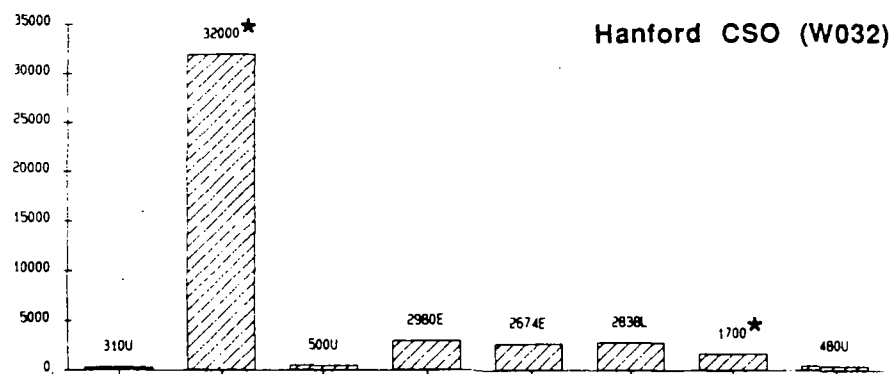


Figure 4-37. Concentrations of selected organic compounds in sediments collected from CSOs in the Elliott Bay project area.

CONCENTRATION ($\mu\text{g/kg}$ dry weight)



LEGEND

* EXCEEDS HAET

Letter following a concentration (e.g., B, E, L, or U) is the data qualifier. See Appendix A.

Figure 4-37. (Continued).

TABLE 4-21. RELATIVE PERCENT DISTRIBUTION OF PAH IN CSOs DISCHARGING INTO THE ELLIOTT BAY PROJECT AREA

	Denny Way (W027)	Vine (069)	Connecticut (W029)	Lander (W030)	Hanford (W032)	Michigan (W039)	Brandon (W041)	Street Dust ^a	Street Dust ^b
LPAH									
Naphthalene	<1	5	<1	ND ^c	41	<1	14	0	0
Acenaphthene	1	5	<1	ND	<1	10	<1	0	0-7
Acenaphthylene	<1	4	<1	ND	<1	<1	<1	0	0
Anthracene	13	18	25	ND	9	14	13	0	0-18
Fluorene	5	5	<1	ND	<1	17	<1	0	0-7
Phenanthrene	80	68	75	ND	49	44	87	100	68-100
Total LPAH (ug/kg)	E3,500 ^d	E6,500 ^d	E560 ^d	ND	E1,940 ^d	E9,790 ^d	E3,220 ^d	1,200-1,600 ^e	640-3,400 ^e
HPAH									
Benzo(a)anthracene	7	<1	10	<1	7	8	<1	0-12	0-12
Benzo(k)fluoranthene	7	13	<1	<1	<1	5	10	0-16	0-24
Benzo(a)pyrene	21	10	<1	<1	<1	6	<1	0-9	0-13
Chrysene	13	18	26	<1	18	14	<1	0-19	0-23
Pyrene	18	23	30	40	39	20	37	26-52	0-52
Fluoranthene	18	23	34	60	36	17	42	26-48	24-100
Dibenzo(a,h)anthracene	<1	<1	<1	<1	<1	3	<1	0	0
Indeno(1,2,3-c,d)pyrene	3	<1	<1	<1	<1	8	<1	0	0
Benzo(b)fluoranthene	7	13	<1	<1	<1	11	11	0	0
Benzo(g,h,i)perylene	3	<1	<1	<1	<1	7	<1	0	0
Total HPAH (ug/kg)	E17,500 ^d	E15,000 ^d	E940 ^d	E400 ^d	E1,900 ^d	E34,700 ^d	E9,970 ^d	3,100-9,480 ^e	780-9,480 ^e

^a Commercial and industrial sites (Galvin and Moore 1982).

^b All sites - residential, commercial, industrial (Galvin and Moore 1982).

^c ND = Not detected.

^d Values reported as dry-weight concentrations. E = Estimated value.

^e Street dust values reported as wet-weight concentrations with an estimated moisture content of 10 percent or less (Galvin, D., 15 July 1988, personal communication).

The concentration of 4-methylphenol exceeded HAET (1,200 ug/kg) in the sediments from the Brandon CSO (E140,000 ug/kg), Hanford CSO (32,000 ug/kg), and the Michigan CSO (E16,000 ug/kg). 4-Methylphenol was undetected (130-650 ug/kg detection limit) in the remaining CSOs, which indicates that there are specific sources of 4-methylphenol in the Brandon, Hanford, and Michigan CSOs.

PCBs were a major contaminant in the Michigan CSO. The concentration of PCBs in the Michigan CSO sediment (E35,400 ug/kg) exceeded the concentration measured in other CSOs by 1-2 orders of magnitude.

4.4.2 Lead in Drain Sediments in Relation to Distance from Inactive Smelter on Harbor Island

A secondary lead smelter operated on Harbor Island from 1937 to 1984. Soil and drains near the smelter have been contaminated with lead from historic smelter emissions. PSAPCA measured lead in concentrations as high as 182,000 mg/kg in the soils in the immediate vicinity of the smelter (PSAPCA 1980). In addition, PSAPCA reported that smelter emissions contained 4 ug/m³ of lead in 1974 reducing to 1 ug/m³ by 1981 (PSAPCA 1983a). The Lander CSO/SD (105), which serves the smelter property has also been contaminated with lead from the smelter. Sediment collected from the drain by Metro in 1984 contained as much as 358,000 mg/kg of lead (Hubbard and Sample 1988).

Lead emitted from the smelter has probably deposited over a large portion of the project area. The concentration of lead measured in the drain sediments has been plotted vs. the distance between the center of each drainage basin to the smelter to determine whether there is any relationship between the contamination found in the drains and past smelter emissions. Lead concentrations generally decrease with distance from the smelter as shown in Figure 4-38. This apparent relationship suggests that the lead contamination found in the drain sediments may have been, at least in part, related to historical smelter emissions.

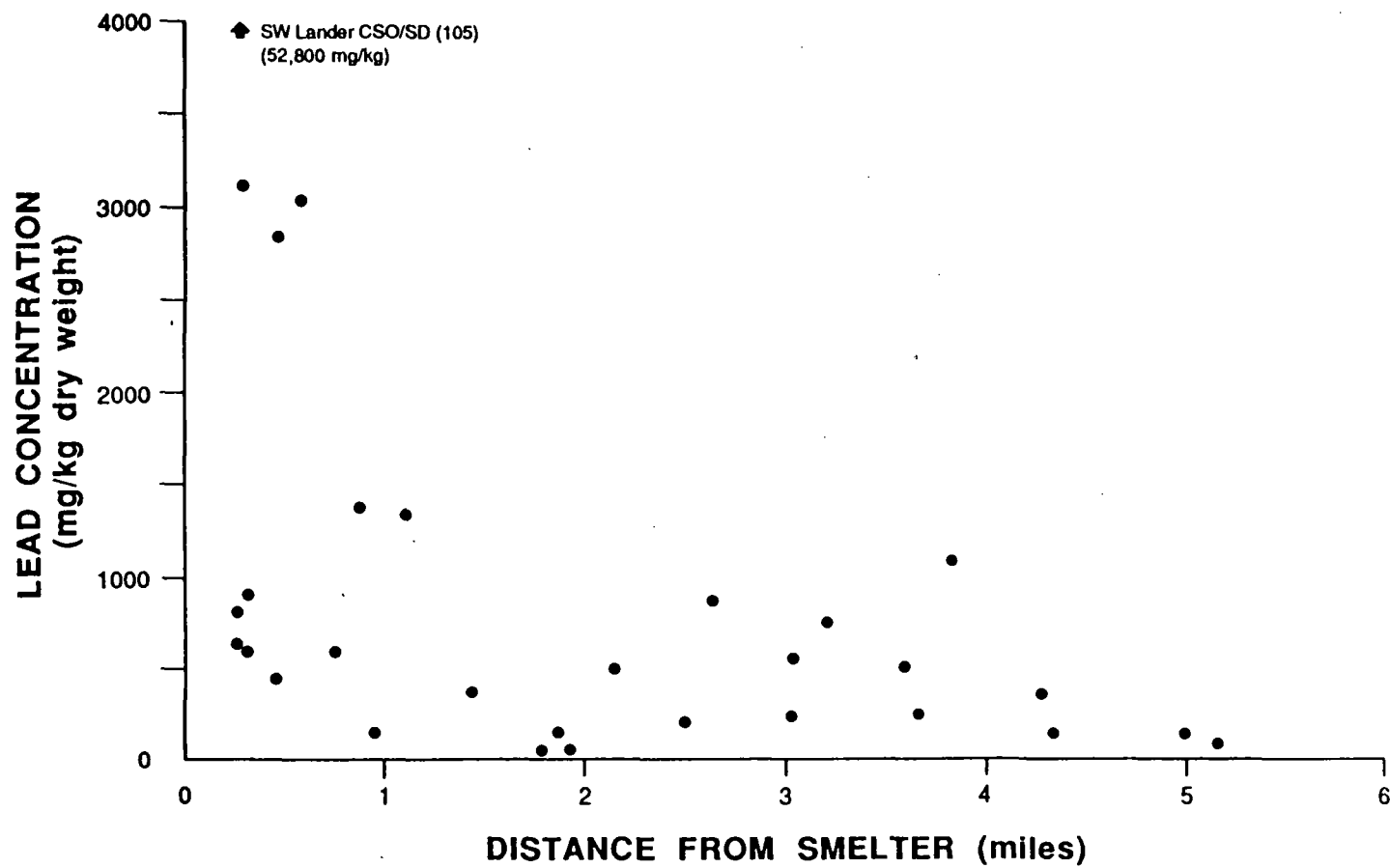


Figure 4-38. Concentrations of lead in drain sediments vs. distance from smelter.

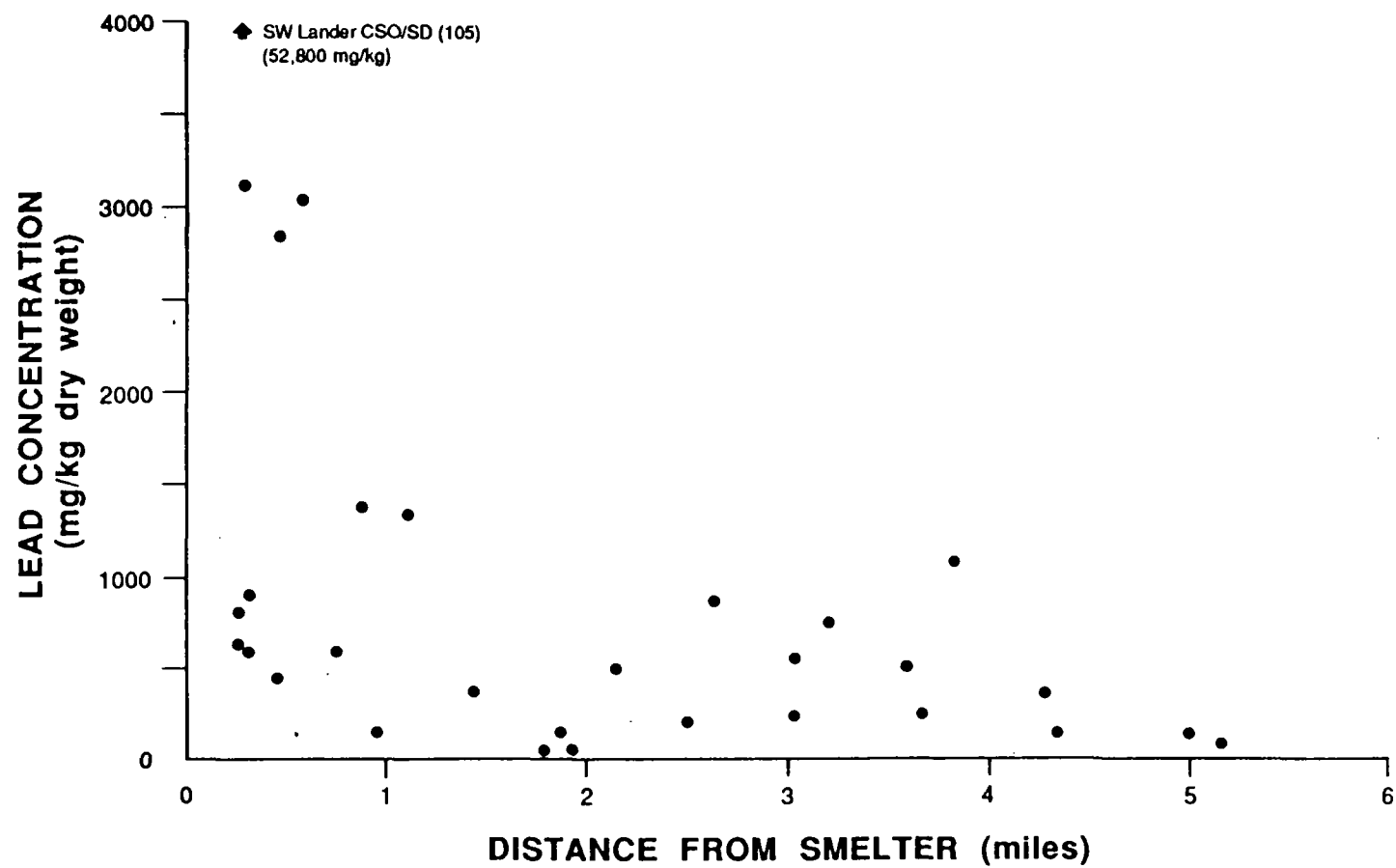


Figure 4-38. Concentrations of lead in drain sediments vs. distance from smelter.

4.4.3 Metals in Duwamish SD and Fox S. CSO/SD (116)

Shipyards are located in the lower basins of the Duwamish SD and Fox S. CSO/SD (116). Both of these drains exceeded the HAET or the 90th percentile concentration for several metals: arsenic, antimony, cadmium, copper, lead, and zinc. The Duwamish SD exhibited the highest concentrations of arsenic, antimony, mercury, and zinc observed in the study.

It has been reported that, in the past, shipyards in the project area used slag from a copper smelter in British Columbia as sandblast material (Dexter et al. 1981). Although metals analyses of the British Columbia slag are limited, the available information indicates that the slag contained elevated concentrations of copper (approximately 1,000 mg/kg; Dexter et al. 1981). Available information on the composition of slag material from a copper smelter in Tacoma (copper concentrations range from 4,000-5,000 mg/kg) was used in the following analyses to compare the distribution of metals in the drains with the distribution in sandblast material and offshore sediments.

Offshore sediment data are available for a sample from the head of Slip 3 (Station DR-12; see Figure 4-24). This station exceeded the 90th percentile concentrations for arsenic (449 mg/kg), copper (386 mg/kg), and zinc (969 mg/kg) (PTI and Tetra Tech 1988). The shipyard (Marine Power and Equipment) in the Fox S. CSO/SD (116) basin is located along the south edge of Slip 3, and its drydocks and synchrolift are located in Slip 3. During an inspection of Marine Power and Equipment, divers from the U.S. EPA observed sandblast grit in the sediment offshore of the shipyard (Karna, D., 14 April 1988, personal communication). The heaviest deposits were located beneath the synchrolift. Marine Power and Equipment is currently operating under a Consent Decree, which stipulates implementing best management practices to prevent the discharge of sandblast materials to the waterways (Ecology, no date).

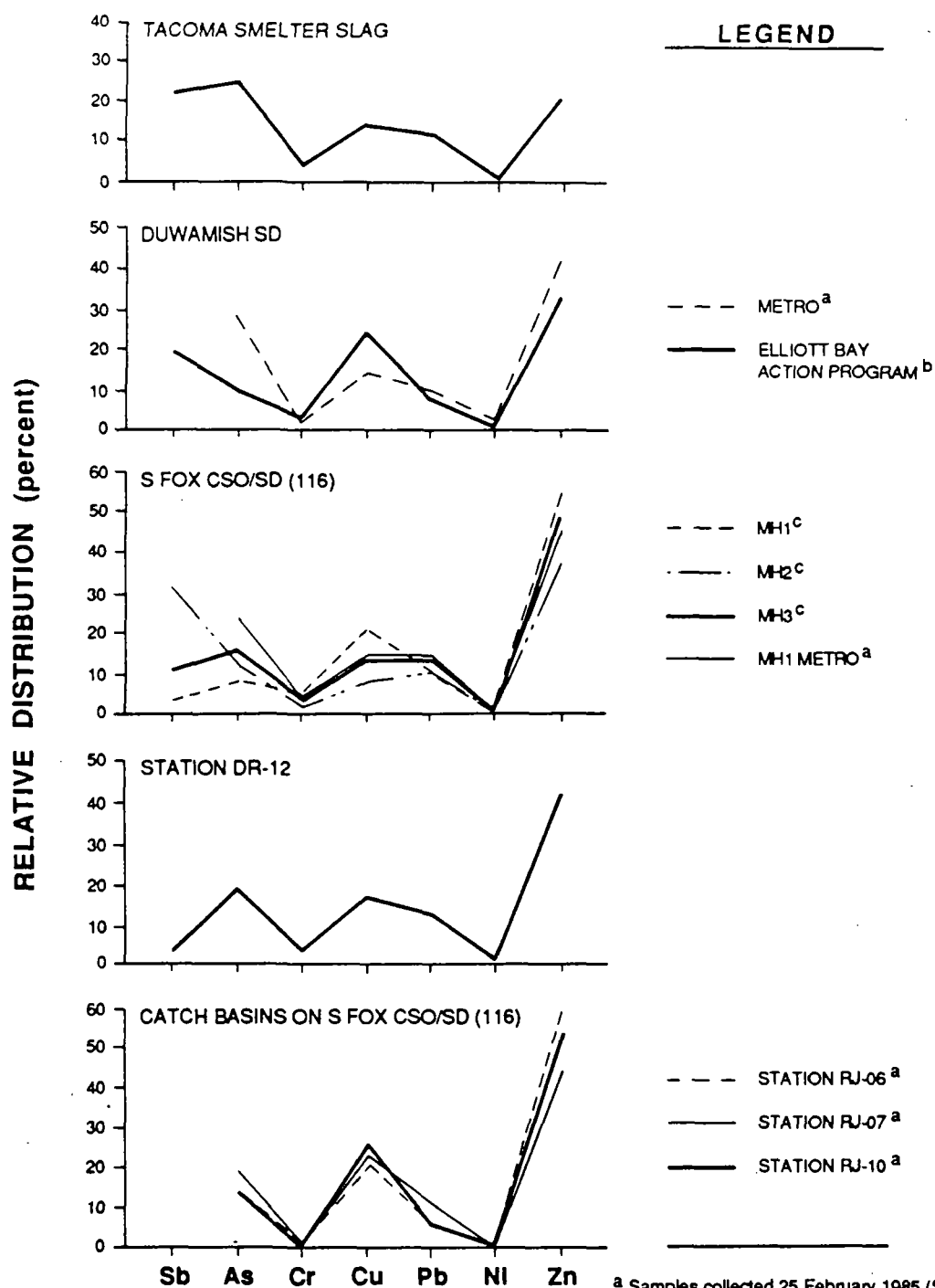
The Fox S. CSO/SD (116) discharges into the Duwamish River immediately south of Slip 3 (see Figure 4-24). Sediment samples have been collected by Metro and the study from five manholes on the Fox S. CSO/SD and nine catch

basins on shipyard property that are connected to the Fox S. CSO/SD, (Sample, T., 23 October 1987, personal communication) (see Figure 4-31). Antimony was not analyzed in Metro's source sediment samples (Sample, T., 23 October 1987, personal communication). During both sampling efforts, sampling personnel reported the presence of sandblast grit throughout the shipyard area. In addition, the physical description of the samples collected from the drain during this investigation suggested that sediments in the drain contained substantial amounts of sandblast grit. The samples were described as coarse-grained, black sediment. Offshore sediment samples were collected from a single station located near the mouth of the Duwamish SD, but no chemistry data are available for stations offshore of this drain.

In general, the relative distribution of metals was similar in the offshore sediments, drain and catch basin sediments, and smelter slag (Figure 4-39). Typically, the abundances of arsenic, copper, and zinc were high in these samples. However, the relative abundance of zinc was generally lower (20 percent vs. 35-58 percent) in the slag than in the sediment samples. Zinc is commonly used in marine paints as an antifoulant (Bellinger and Benham 1978). Antifoulant paints are generally removed prior to repainting by sandblasting. Therefore, zinc would probably be present in spent sandblast grit. The relative distribution (percent) of arsenic, copper, and zinc (percent) was similar in the catch basin and drain sediments [from both the Duwamish SD and the Fox S. CSO/SD (116)]:

<u>Chemical</u>	<u>Catch Basin</u>	<u>Drain</u>
Arsenic	14-19	8-28
Copper	21-26	8-24
Zinc	44-58	32-54

The historical sample from the Duwamish SD contained a greater abundance of arsenic (28 percent) than the other samples collected during this study, which may be due to absence of antimony data for the historical samples (see Figure 4-39). Antimony is a major constituent of the slag and the Elliott Bay Action Program sample collected from the Duwamish SD. If antimony is excluded from the Elliott Bay Action Program drain sediment sample and slag composition calculations, the relative abundance of arsenic



^a Samples collected 25 February 1985 (Sample, T., 23 October 1987, personal communication).
^b Samples collected 16 October 1987 (this study).
^c Samples collected 27 September 1987 (this study).

Figure 4-39. Comparison of relative percent distribution of metals in Tacoma Smelter slag, offshore sediments, and drains serving shipyards.

in the samples increases to 14 percent for the sample collected in this study, and 33 percent for the historical sample.

The relative distribution of metals in the sediments collected from the Fox S. CSO/SD (116) indicates that the metals contamination originated from the same or similar sources. With the exception of antimony in MH2, the relative distribution of metals in MH1, MH2, MH3, and MH4 was nearly identical (see Figure 4-39). The sample collected by Metro from MH5 (see Figure 4-31), located on the southern end of Fox S. contained a higher proportion of lead (29 percent) and a lower proportion of arsenic (5 percent) than was measured in MH1-MH4 (10-14 percent lead, and 8-24 percent arsenic). This difference in the relative distribution of metals composition indicates that metals in the southern branch of the Fox S. CSO/SD (116) were contributed from a different source. Because of past problems with fugitive dust emissions reported at the shipyard and similarities in the relative distribution of metals composition in the drain sediments, it is likely that contamination in MH1-MH4 was caused by sandblasting activities at the shipyard. In addition, similarities in the relative distribution of metals in the Duwamish SD sediment sample also indicate that sandblasting activities may have been a major source of the contamination in this drain as well.

The relative distribution of metals in the offshore sediment sample from Slip 3 (Station DR-12) was also similar to the relative distribution in the catch basin and drain samples (see Figure 4-39). Peaks occur with arsenic, copper, and zinc. These similarities, in conjunction with the visual evidence of sandblast materials in the sediments offshore of the shipyard, indicate that contamination at this station was most likely from the sandblasting operations at the shipyard.

4.5 CSO AND STORM DRAIN RANKINGS

The CSOs and storm drains sampled during the Elliott Bay sampling program have been ranked based on the criteria presented in Tetra Tech (1988g). The ranking system is provided to help prioritize problem drains for future detailed investigations (i.e., contaminant tracing, source identification, and source control activities). To account for the many

factors that influence receiving environment contamination from individual CSOs and storm drains, three different criteria have been used in the evaluation:

- The number of problem chemicals identified in each drain
- The magnitude of exceedance of reference area sediment chemistry conditions (i.e., EAR)
- A contaminant loading index.

The number of problem chemicals (Section 4.1) identified in each drain is indicative of the variety of sources responsible for contamination in the drain sediments. A large number of problem chemicals may indicate that there are multiple sources contributing to the contaminant problem or that a single source is discharging a complex mixture of contaminants. Drains that have a large number of problem chemicals in the sediments were assigned a higher priority. The problem chemicals identified in each drain are listed in Table 4-1. The Fox S. CSO/SD (116)-MH3, Michigan CSO (W039), Slip 4 CSO/SD (117), Fox S. CSO/SD (116)-MH1, Slip 6 SD, and Michigan SD rank as the highest priority drains based on the number of problem chemicals (i.e., >10 problem chemicals) (Table 4-22).

The magnitude of the EAR was calculated based on the sum of the EARs for the individual problem chemicals identified in each drain. The sum of the individual EARs is an indication of the severity of the contamination problem in each drain. EARs are summarized in Appendix F. Based on the sum of the individual EARs, the following drains rank as the highest priority drains (Table 4-23): Slip 4 CSO/SD (117), Duwamish SD, SW Lander CSO/SD (105), Fox S. CSO/SD (116)-MH2.

Loading indices take into account both the measured concentration of contaminants in the drain sediments and estimated annual discharges from each drain (based on drainage basin area, land-use characteristics, and average annual runoff). Although loading indices are not a true contaminant loading value, they provide an indication of the potential magnitude of effects on

TABLE 4-22. CSO AND STORM DRAIN RANKING BASED ON
NUMBER OF PROBLEM CHEMICALS^a

	Number of Problem Chemicals
Fox S. CSO/SD (116)-MH3	32
Michigan CSO (W039)	19
Slip 4 CSO/SD (117)	16
Fox S. CSO/SD (116)-MH1	13
Slip 6 SD	11
Michigan SD	11
SW Hanford CSO/SD (162)	9
Brandon CSO (W041)	8
Duwamish SD	7
Diagonal Way CSO/SD (111)	7
Interbay CSO/SD (068)	6
Longfellow Creek	5
16th Ave. S. SD	5
Vine St. CSO (069)	5
Hanford CSO (W032)	5
16th Ave. SW CSO/SD (104)	4
Fox S. CSO/SD (116)-MH2	4
11th Ave. SW CSO/SD (077)	4
Denny Way CSO (W027)	3
SW Spokane CSO/SD (163)	3
SW Lander CSO/SD (105)	3
S. Nevada SD	3
Pier 91 SD	3
SW Spokane CSO/SD (102)	3
Isaacson CSO/SD (156)	2
SW Florida CSO/SD (106)	2
Diagonal Ave. S. SD	2
SW Florida SD (36 in)	1
S. Hinds CSO/SD (107)	1
Lander CSO (W030)	1
SW Hinds CSO/SD (099)	1
I-5 SD	1
56th Ave. SW SD	1
Connecticut CSO (W029)	0
SW Lander SD (15 in)	0
SW Florida CSO/SD (098)	0
SW Lander SD (21 in)	0
SW Dakota SD	0
SW Idaho SD	0
SW Graham SD	0
2nd Ave. S. SD	0
S. 96th SD	0
Slip 4 SD	0
S. River SD	0

^a Problem chemical defined as a chemical whose concentration in drain sediments exceed the high AET value or is in the 90th percentile for the drains sampled (if no AET value is available).

TABLE 4-23. CSO AND STORM DRAIN RANKING BASED ON EAR^a

CSO and Storm Drain	EAR
Slip 4 CSO/SD (117)	47,000
Duwamish SD	42,000
SW Lander CSO/SD (105)	42,000
SW Hanford CSO/SD (162)	40,000
Fox S. CSO/SD (116)-MH2	26,000
Fox S. CSO/SD (116)-MH3	18,000
Diagonal Way CSO/SD (111)	12,000
Brandon CSO (W041)	11,000
Michigan CSO (W039)	14,000
Interbay CSO/SD (068)	4,700
Hanford CSO (W032)	3,200
Longfellow Creek	2,100
Fox S. CSO/SD (116)-MH1	2,000
SW Hinds CSO/SD (099)	1,400
Slip 6 SD	1,400
Michigan SD	1,400
16th Ave. S. SD	960
16th Ave. SW CSO/SD (104)	720
Vine Str. CSO (069)	400
SW Spokane CSO/SD (163)	340
11th Ave. SW CSO/SD (077)	320
S. Nevada SD	280
Pier 91 SD	280
Denny Way CSO (W027)	210
SW Spokane CSO/SD (102)	190
S. Hinds CSO/SD (107)	150
SW Florida CSO/SD (106)	100
Isaacson CSO/SD (156)	93
Diagonal Ave. SD	90
I-5 SD	78
Lander CSO (W030)	36
Lander SD (15 in)	10
56th Ave. SW SD	0.48

^a Sum of the individual EAR values for all problem chemicals.

the receiving environment. Drains that serve a relatively large area, and therefore contribute a larger volume of discharge to the waterways are expected to have a greater impact on the receiving environment. Loading indices are summarized in Appendix F. CSO and storm drain rankings based on the sum of the individual problem chemical loading indices in each drain are presented in Table 4-24. The SW Hanford CSO/SD (162) and SW Lander CSO/SD (105) are the highest priority drains based on loading index calculations.

CSOs and storm drains that have been given a high priority for further source investigations have been selected based on the above criteria. Any drain that ranked as a highest priority based on either of the three criteria was selected as a high-priority drain. The following drains received a high-priority ranking:

- Fox S. CSO/SD (116)
- Michigan CSO (W039)
- Slip 4 CSO/SD (117)
- Duwamish SD
- SW Lander CSO/SD (105)
- SW Hanford CSO/SD (162)
- Slip 6 SD
- Michigan SD.

Many of the other drains in the project area warrant further investigation to identify contaminant sources in the basin. Assuming that funding for further investigations is limited, the high-priority drains listed above are simply recommended as the drains that should be investigated first. Contaminated sources in the other drains can be investigated as funding

TABLE 4-24. CSO AND STORM DRAIN RANKING BASED ON LOADING INDEX

CSO and Storm Drain	Total Loading Index ^a
SW Hanford CSO/SD (162)	1,050,000
SW Lander CSO/SD (105)	1,040,000
Michigan CSO (W039)	395,000
Fox S. CSO/SD (116)-MH3	329,000
Fox S. CSO/SD (116)-MH1	309,000
Hanford CSO (W032)	285,000
Isaacson CSO/SD (156)	279,000
Fox S. CSO/SD (116)-MH2	232,000
Duwamish SD	209,000
Longfellow Creek	162,000
Slip 4 CSO/SD (117)	159,000
Brandon CSO (W041)	128,000
11th Ave. SW CSO/SD (077)	84,700
S. Nevada SD	62,600
S. Hinds CSO/SD (107)	54,800
SW Spokane CSO/SD (102)	50,700
Diagonal Way CSO/SD (111)	37,800
16th Ave. S. SD	31,100
SW Florida CSO/SD (106)	24,200
16th Ave. SW CSO/SD (104)	9,050
SW Spokane CSO (163)	9,040
Interbay CSO/SD (068)	8,860
Vine St. CSO (069)	8,080
Lander CSO (W030)	7,270
I-5 SD	7,140
SW Hinds CSO/SD (099)	5,530
Denny Way CSO (W027)	3,580
Slip 6 SD	3,100
Michigan SD	3,100
Pier 91 SD	600
Diagonal Ave. SD	70
SW Florida SD (36 in)	8
Lander SD (15 in)	3
56th Ave. SW SD	1

^a Calculated as the sum of the problem chemical concentration in drain sediments (mg/kg) x average annual discharge (Mgal/yr) for all problem chemicals.

allows. This ranking procedure has been based entirely on evaluations of the drain sediment chemistry data.

Two additional drains, the SW Florida CSO/SD (098) and the S. 96th St. SD, are recommended for inclusion on the list of high-priority drains because specific sources of contamination have been identified in the drainage basins. Although contamination was not found in the drain sediments during the sampling, information obtained from Metro and Ecology indicate that there are ongoing sources of contamination in both basins. Additional high-priority problem drains have also been identified based on the results of the source-receiving environment sediment evaluations (see Section 5.0).

Runoff from the Wyckoff property has been identified as an ongoing source of PAH and pentachlorophenol to the SW Florida CSO/SD (098) (Sample, T., 27 March 1987, personal communication). Ecology has documented that soil in the S. 96th SD basin is contaminated with benzo(a)pyrene (800 mg/kg in soil excavated during the Renton Effluent Transfer Project), and has evidence that there are multiple contaminant sources in the drainage basin (Cargill, D., 25 February 1988, personal communication).

Advance Electroplating, a metal plating facility, has been identified as an historic source of metals contamination in the S. 96th St. SD basin (Ecology and Environment 1986). Prior to 1982, Advance Electroplating was permitted (NPDES) to discharge process wastewater and cooling water to the S. 96th St. SD. Ecology and Environment (1986) reported that the drainage ditch has been filled in and the potential human health risk is low as long as the buried materials are undisturbed. Advance Electroplating is currently permitted under Metro's industrial pretreatment program to discharge wastewater to the sanitary sewer system. All spent electroplating solutions, sludges, and solids generated at the facility are currently transported offsite for disposal.

On 13 May 1986, Metro collected sediment samples from five locations in the S. 96th St. SD system (Sample, T., 13 November 1986, personal communication). Elevated concentrations of chromium (365 mg/kg) were measured in the ditch immediately downstream of the Precision Engineering property (see

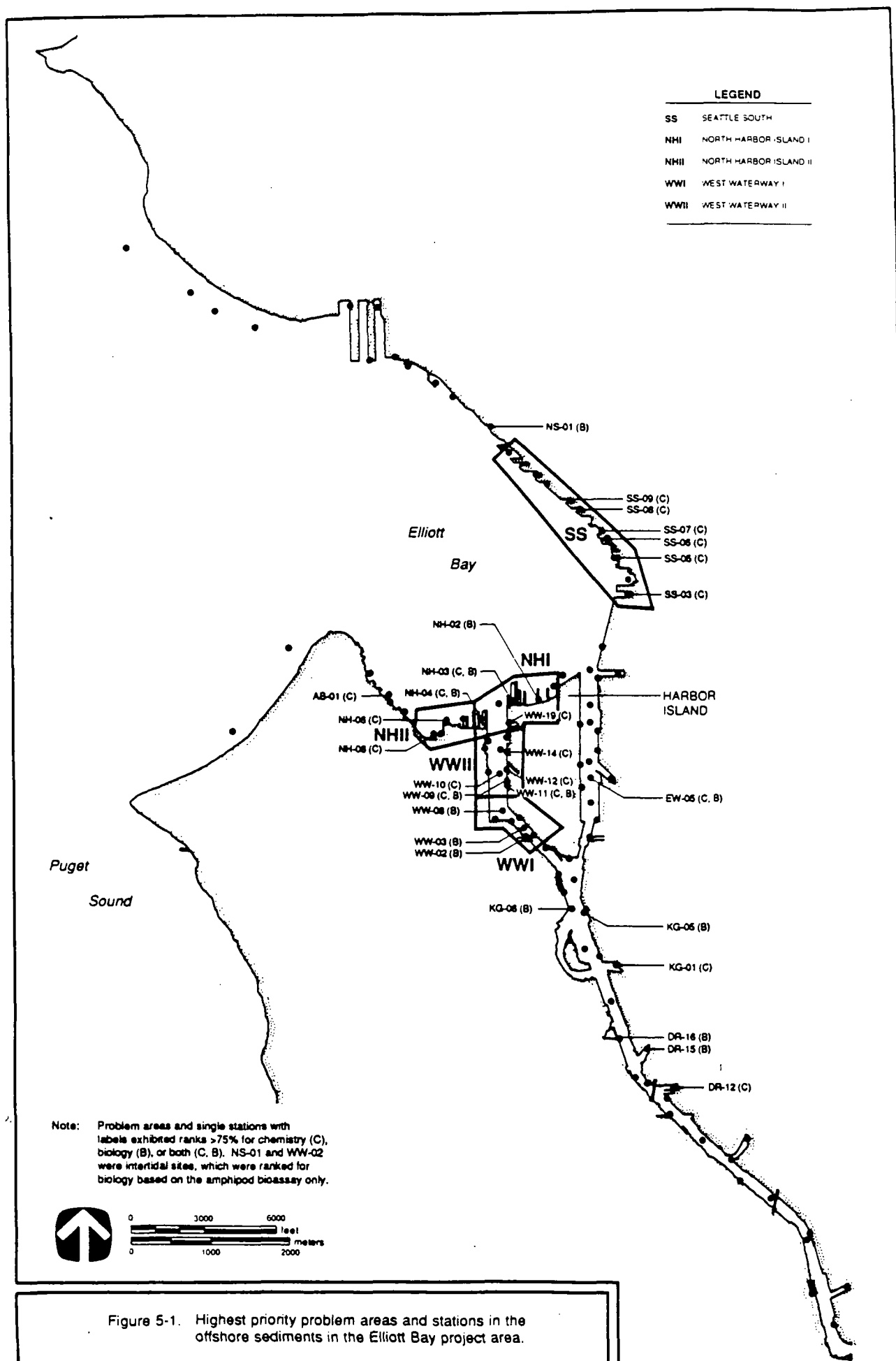
Map 4 in Map Appendix) and at the downstream end of the drain near the mouth (542 mg/kg). The concentration of chromium at the three other sites ranged between 25 and 33 mg/kg. Precision Engineering is currently under investigation by Ecology and has submitted a work plan to investigate soil and groundwater contamination on their property, and to sample sediments in the S. 96th St. SD downstream of their property (Sweet-Edwards/EMCON 1988). Other potential contaminant sources that have been identified in the S. 96th St. SD basin include an asphalt manufacturer and two fill areas (Cargill, D., 25 February 1988, personal communication).

5.0 SOURCE EVALUATIONS

Problem area identification and prioritization in the Elliott Bay project area was based on a series of chemical and biological indices (PTI and Tetra Tech 1988). These indices were used to relate conditions at sites within the project area to reference conditions in relatively uncontaminated embayments of Puget Sound. Study areas that exhibited high concentrations of chemical contamination in sediment and adverse biological effects received a ranking of "high priority" for evaluation of contaminant sources and remedial actions. The biological variables used to characterize toxic effects included bioaccumulation of selected chemical contaminants in fish tissue, histopathology of fish livers, mortality of amphipods in sediment bioassays, and abundance of benthic infauna communities.

In the following sections, available information on potential sources (i.e., CSOs, storm drains, spills, industrial facilities, and groundwater) and offshore sediment data were evaluated to link sources to problem areas in the receiving environment. Source to receiving environment evaluations were completed for the highest priority problem areas (i.e., Seattle South Waterfront, North Harbor Island I and II, and West Waterway I and II. Evaluations have also been completed for individual problem stations (i.e., NS-01, EW-05, AB-01, KG-01, KG-05, KG-06, DR-12, DR-15, and DR-16) that were located outside the boundaries of the problem areas identified in the receiving environment (Figure 5-1) (PTI and Tetra Tech 1988). Five main factors were considered in the evaluations:

- Proximity of the potential source to the problem station offshore
- Similarity of problem chemicals in drain and receiving environment sediments



- Similarity of the relative percent distribution of chemicals within the drain and receiving environment sediments
- The spatial distribution of contaminants in the offshore sediments
- Available information on past or ongoing practices that may contribute to the contamination observed in the receiving environment.

5.1 PROBLEM AREAS

5.1.1 Seattle South Waterfront Problem Area

The Seattle South Waterfront was designated a high-priority problem area on the basis of sediment chemistry (PTI and Tetra Tech 1988). The problem area extends south of Pier 46 and north to Pier 70 and includes 10 stations, SS-03 through SS-12 (see Figure 4-7). Sediments were highly contaminated throughout this problem area, with localized sites of extreme contamination (PTI and Tetra Tech 1988). The Seattle South Waterfront had 17 chemicals exceeding the HAET, more than any other problem area (Table 5-1). The highest concentrations of many problem chemicals in this area and frequently in the entire study occurred at Stations SS-03 and SS-09 (see Figure 4-5) (PTI and Tetra Tech 1988). Biological effects observed in the problem area were much less severe than expected based on the degree of the chemical contamination (PTI and Tetra Tech 1988).

Concentrations of nearly all metals were elevated throughout the area. The highest concentrations of arsenic, cadmium, chromium, lead, nickel, selenium, and zinc found in the study were located at stations along the Seattle South Waterfront. Metals identified as problem chemicals included copper, lead, zinc, mercury, cadmium, and silver (PTI and Tetra Tech 1988). Although elevated concentrations of chromium and nickel were observed, data for these two metals were not used in characterizing the area as a problem area because the AET values were not acceptable (see Section 4.1).

TABLE 5-1. HAET AND LAET EXCEEDANCES IN THE SEATTLE SOUTH WATERFRONT PROBLEM AREAS^a

Station	HAET Exceedances ^b																	LAET Exceedances ^c
	LPAH	HPAH	PCBs	CU	PB	ZN	HG	CD	AG	p,p'- DDT/ODE/DDO	PHNL	2,4MEPHN	BNZO	1,4DICLBNZ	BUTBNZPH	DMP	TOC	
SS-03		X		X		X							X	X		X		HG, LPAH, AS, PB, CD, PCBs, DDO [AG, DMP]
SS-04	X	X								X						X		HG, PB, PCBs, ZN [AG]
SS-05	X	X							X							X		HG, PB, PCBs, DDO, ZN [RETENE, CARBAZOLE, DINOCT]
m10015 ^d	X	X																HG, PCBs
S0090 ^e	X	X	X		X	X	X	X		X								
SS-06	X	X																HG, PB, PCBs, ZN [CD, AG]
SS-07	X	X					X		X			X						PB, CU, PCBs, ZN
S0065 ^e		X																HG, PCBs
SS-08	X	X															X	HG
SS-09	X	X	X		X	X	X	X		X				X				CU, DMP, PHNL [ALDRIN, RETENE, CARBAZOLE, AS, CR]
SS-10	X	X																HG, ZN [CR, NI]
C061 ^e	X	X									X							PCBs, ZN
SS-11		X														X		HG, LPAH, PCBs, ZN [AG]
B061 ^e		X	X															PCBs, DDE, ZN
SS-12																		[AG]

^a LPAH - Signifies AET exceedances for the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene, or any of these compounds individually. To simplify the presentation of AET exceedances in this table, exceedances of AET for 1-methylphenanthrene, 2-methylnaphthalene, biphenyl, and dibenzofuran are included under LPAH. These compounds covaried with LPAH but are not included in LPAH sums.

HPAH - Signifies AET exceedances for the sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)-anthracene, and benzo(g,h,i)perylene, or of any of these compounds individually.

CU - copper
PB - lead
ZN - zinc
HG - mercury
CD - cadmium
AG - silver
AS - arsenic

BNZO - benzyl alcohol
BNZACID - benzoic acid
1,4DICLBNZ - 1,4-dichlorobenzene
BUTBNZPH - butyl benzyl phthalate
DMP - dimethyl phthalate
TOC - total organic carbon
DINOCT - di-n-octyl phthalate

PHNL - phenol
4MEPHNL - 4-methylphenol
2MEPHNL - 2-methylphenol
2,4MEPHNL - 2,4-dimethylphenol
TOTXYLENE - total xylenes
CR - chromium
ENDALD - endrin aldehyde
PCP - pentachlorophenol

^b Chemicals exceeding HAET for Puget Sound.

^c Chemicals exceeding LAET for Puget Sound. Chemicals shown in brackets exceeded 90th-percentile concentrations but did not exceed any AET. Chemicals exceeding both AET and 90th-percentile concentrations are not bracketed.

^d Malins et al. (1982).

^e Romberg et al. (1984).

U.S. EPA, BTL and Tetra Tech (1988)

Spatial gradients of metal contamination were not apparent in the offshore sediments. Typically, concentrations were elevated throughout the area, with extreme concentrations at isolated stations (PTI and Tetra Tech 1988). Over half of the Seattle South Waterfront stations exceeded the LAETs for lead (300 mg/kg), zinc (260 mg/kg), and mercury (0.41 mg/kg) (see Table 5-1). These three metals exhibited similar spatial gradients, with maximum concentrations observed at Station SS-09 (lead=71,100 mg/kg, zinc=E6,010 mg/kg, and mercury=E3.89 mg/kg). Chemical concentrations at adjacent stations were at least 1 order of magnitude lower, indicating localized sources of contamination at Station SS-09. The highest concentration of cadmium (17.2 mg/kg) in the study was found in the sediments from Station SS-09. The spatial distribution of copper was uneven, exceeding the HAET (800 mg/kg) only at Station SS-03 (1,040 mg/kg) and exceeding the LAET (310 mg/kg) at Stations SS-07 and SS-09. Silver concentrations were elevated at the two stations (see Figures 4-5 and 4-7) southeast of the Denny Way CSO (E4.98 mg/kg at Station SS-12, and E4.31 mg/kg at Station SS-11). Concentrations of silver at Stations SS-05 (E5.85 mg/kg) and SS-07 (E5.85 mg/kg) also exceeded the HAET (5.2 mg/kg).

PAH compounds were the most commonly occurring contaminants in the Seattle South Waterfront problem area (PTI and Tetra Tech 1988). The highest concentrations of both LPAH and HPAH observed in the study were found in sediment from Station SS-08 (LPAH=632,300 ug/kg, HPAH=E3,174,000 ug/kg). The concentration of total PAH was 40 times greater at Station SS-08 than at adjacent stations, but LPAH concentrations at all stations between SS-04 and SS-10 exceeded the HAET (6,100 ug/kg) (PTI and Tetra Tech 1988). The elevated chemical concentrations in samples recently collected by the Port of Seattle substantiates the characterization of this area as highly contaminated, but does not confirm the extreme contamination observed at Stations SS-08 and SS-09 in the present study (Aggerholm, D., 22 February 1988, personal communication).

PCB concentrations were also elevated along the Seattle South Waterfront, exceeding the HAET (2,500 ug/kg) at three stations and the LAET (130 ug/kg) at 10 stations (see Table 5-1). Although a distinct concentration gradient was not observed, dry-weight values normalized to TOC

tended to decrease from Station SS-03 north to Station SS-07 (PTI and Tetra Tech 1988). The maximum concentration (E3,300 ug/kg) was observed at Station SS-09. The PCB concentration at Station SS-08 was not included in the analysis due to the high detection limits reported for this sample.

Mean concentrations of oil and grease, TOC, and total sulfides were higher along the Seattle South Waterfront than in any other area. p,p'-DDT, p,p'-DDE, and p,p'-DDD at Stations SS-04 and SS-09, and 1,4-dichlorobenzene at Stations SS-03 and SS-09 exceeded HAET concentrations, but high detection limits (p,p'-DDT, p,p'-DDE, p,p'-DDD=24 to 55 ug/kg; 1,4-dichlorobenzene=220 to 7,300 ug/kg) preclude further evaluation of the distributions of these two chemicals. Benzyl alcohol exceeded the HAET (73 ug/kg) at Station SS-03 (E1,300 ug/kg), but was undetected at adjacent stations, possibly due to the high detection limits (690 to 13,000 ug/kg) reported for these samples (PTI and Tetra Tech 1988).

Potential Contaminant Sources--

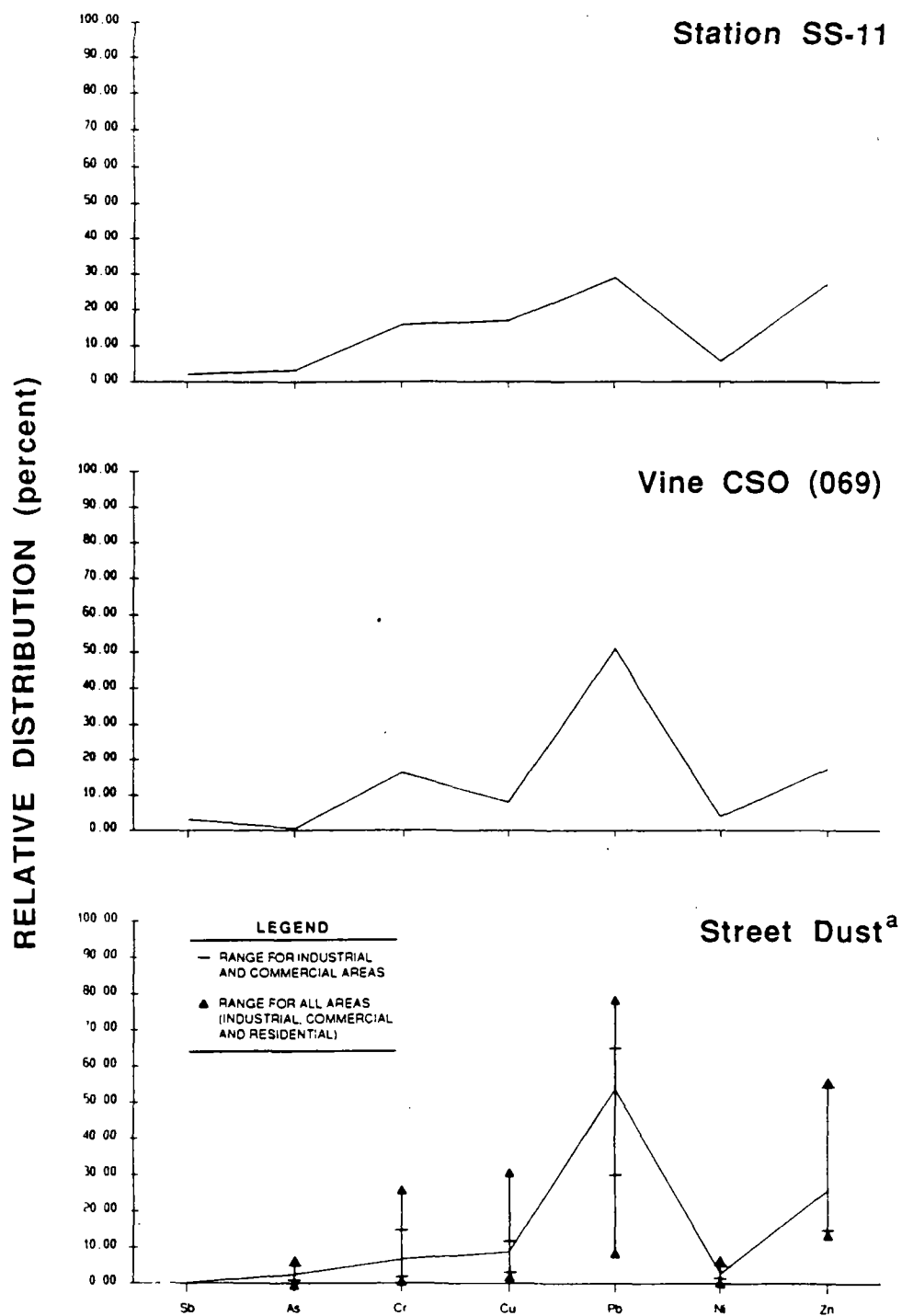
In contrast to other problem areas where extreme chemical contamination is associated with one or two major industries, the Seattle South Waterfront has relatively few current sources of contamination. Many of the stations in this problem area are located near CSOs, which appear to be the most probable sources of local contamination. There are currently seven CSOs discharging along the Seattle South Waterfront (see Figure 4-5). In addition, one CSO, located at the foot of Battery St., was used through the 1950s (Brown and Caldwell 1958). Evaluation of the contributions from drains to offshore contamination was complicated by the fact that of the seven CSOs currently operating in the problem area, only one [Vine CSO (069)] contained sufficient sediment to allow sample analysis. Potential contamination from these CSOs can not be assessed, and several highly contaminated offshore stations were located near their outfalls.

Vine CSO (069)--Five problem chemicals were identified in the Vine CSO (069): lead (850 mg/kg), mercury (E2.23 mg/kg), benzyl alcohol (E170 ug/kg), 2-methylphenol (E660 ug/kg), and LPAH (E6,500 ug/kg) (see Table 4-1). All of these chemicals have been identified as problem chemicals in Seattle

South Waterfront sediments. The offshore stations near the Vine CSO outfall and the problem chemicals observed at these stations are listed in Table 5-1. LPAH and mercury concentrations in the CSO sediment (E6,500 ug/kg and E2.23 mg/kg, respectively) exceeded the HAET (LPAH=6,100 ug/kg; mercury=2.1 mg/kg). In the offshore sediments, LPAH (11,550 ug/kg) also exceeded the HAET, and mercury (1.31 mg/kg) exceeded the LAET (0.41 mg/kg). The Vine CSO appears to be a source of mercury and LPAH in the Seattle South Waterfront problem area.

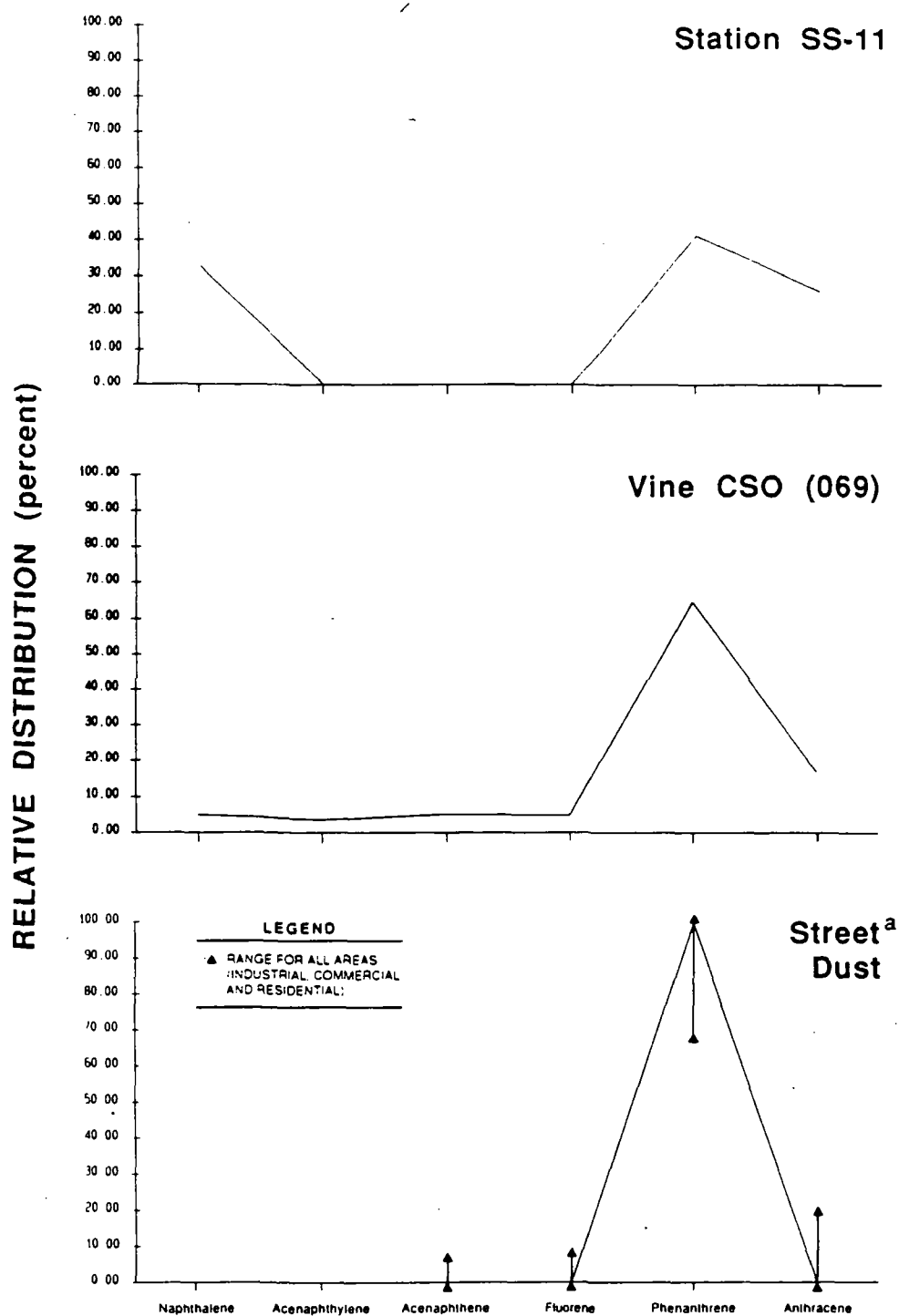
HPAH, PCBs, dimethyl phthalate, p,p'-DDE, and zinc in sediments from Station SS-11 exceeded HAET or LAET concentrations. In the Vine CSO sediments, no chemicals exceeded the HAET, but HPAH, PCBs, and zinc exceeded the LAET. The relative distributions of metals in sediments from offshore Station SS-11 and the Vine CSO are presented in Figure 5-2. The relative distribution of these metals in street dust collected in industrial and commercial areas (Galvin and Moore 1982) is also plotted. The relative distribution of metals in the CSO sediment was similar to the relative distribution of metals in street dust. Therefore, street runoff appeared to be the major source of metal contamination in the CSO sediments. The relative abundances of zinc and copper were greater in sediments from Station SS-11 (19 percent copper, 28 percent zinc) than in the Vine CSO sediments (9 percent copper, 18 percent zinc). These data suggest that although the Vine CSO may have been contributing metals to the offshore sediment, it may not have been the primary source of these contaminants.

The relative distributions of LPAH compounds in sediment from the Vine CSO, Station SS-11, and street dust are presented in Figure 5-3. Phenanthrene is a major component of both the CSO sediments and street dust, indicating that surface runoff may contribute to phenanthrene contamination in the CSO. However, the presence of several LPAH compounds in the CSO sediment that were not observed in street dust suggests additional sources of LPAH contamination. The relative distributions of LPAH compounds in the offshore station and the Vine CSO sediments were somewhat similar. The Vine CSO may have contributed to the presence of various LPAH compounds in the offshore sediments, but additional sources of certain compounds (e.g., naphthalene) were indicated.



^a Reference: Galvin and Moore (1982).

Figure 5-2. Comparison of relative percent distribution of metals in offshore sediment from Seattle South Waterfront problem area and a nearby drain.



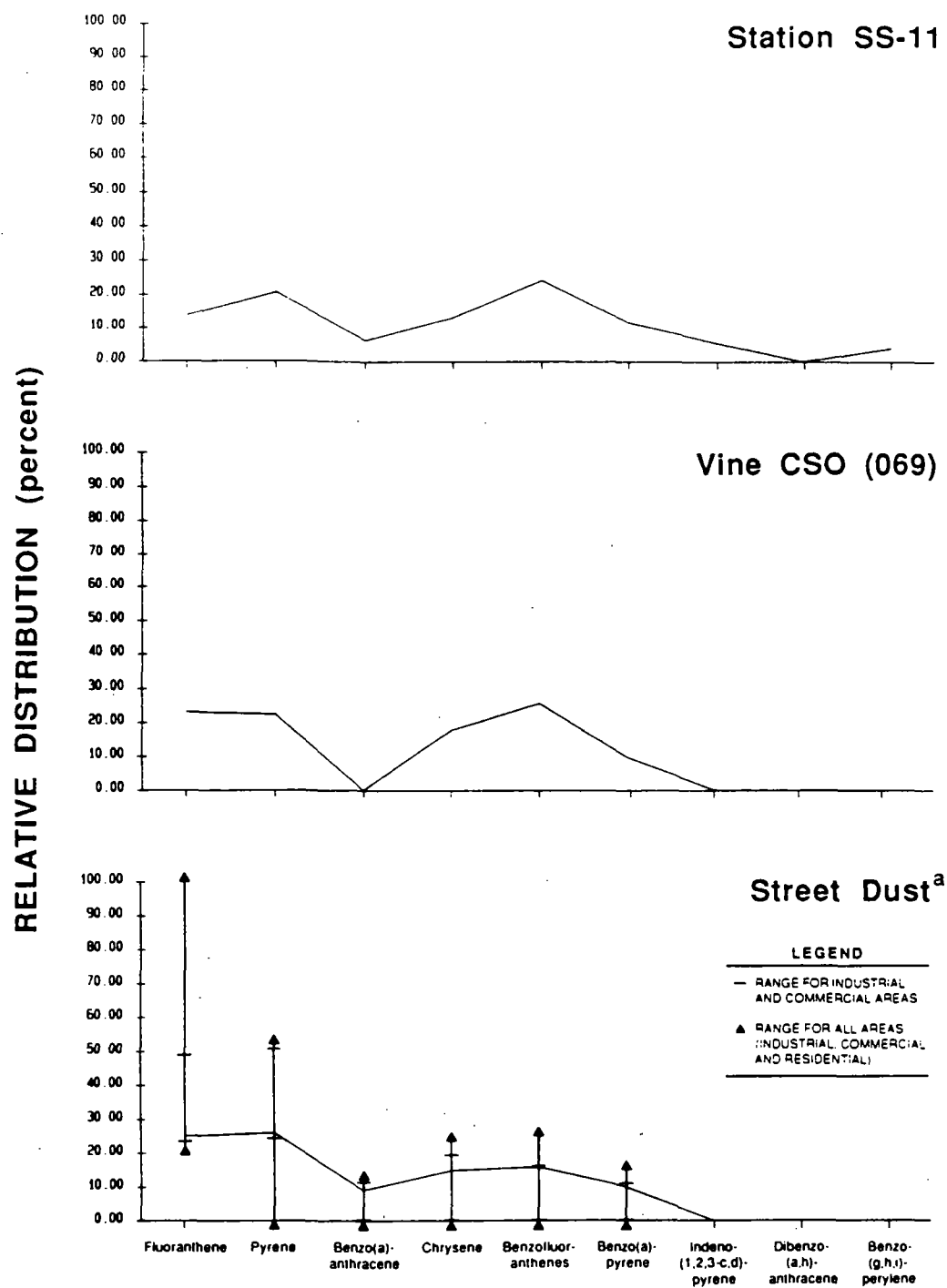
^a Reference: Galvin and Moore (1982).

Figure 5-3. Comparison of relative percent distribution of LPAH in offshore sediment from Seattle South Waterfront problem area and a nearby drain.

The relative distributions of HPAH compounds in sediments from the Vine CSO, Station SS-11, and street dust are presented in Figure 5-4. The relative distribution of HPAH compounds in sediments from the Vine CSO was similar to that observed in street dust. However, the concentration of HPAH compounds in the CSO sediment (15,030 ug/kg) was higher than the concentration measured in street dust (8,050-8,480 ug/kg). Relative distributions of HPAH compounds in the CSO sediments and sediments from offshore Station SS-11 were also similar, suggesting that the storm drain may have contributed to the presence of HPAH in the offshore sediments. However, HPAH compounds were present in the offshore sediments at Station SS-11 that are not found in street dust.

King CSO (W028)--Although no sediments were present in the King CSO (W028), some metals data are available from water samples collected from the drain (see Table 2-2) (Metro 1984). Station SS-03, one of the most highly contaminated stations in the problem area (see Figure 4-5), was located near the King CSO (W028) outfall. In addition, the estimated annual discharge from the King CSO (70 Mgal/yr) exceeds that of any other CSO in the area by 1 order of magnitude (see Table 2-1). Concentrations of copper (97 ug/L) and zinc (180 ug/L) in the King CSO water samples (see Table 2-2) exceeded the acute marine water quality criteria (copper=2.9 ug/L; zinc=95 ug/L) (U.S. EPA 1986b). Both copper and zinc exceeded the HAET in sediments from Station SS-03, the station nearest the CSO outfall. Lead (66 ug/L) and mercury (0.42 ug/L) in the King CSO water samples exceeded the chronic marine water criteria quality (lead=5.6 ug/L; mercury=0.025 ug/L) (U.S.EPA 1986b). Both metals were present in the sediments from Station SS-03 at concentrations that exceeded LAET.

Based on results of the above analyses, the Vine and King CSOs, and possibly the remaining five CSOs, contributed to the contamination observed in the offshore sediments. However, even in the absence of additional source data, several factors indicate that the CSOs do not account for all contaminant input to the Seattle South Waterfront sediments. Many chemicals observed in the offshore sediments were not present in the nearby drains. In addition, many contaminated offshore stations were not located near ongoing



^a Reference: Galvin and Moore (1982).

Figure 5-4. Comparison of relative percent distribution of HPAH in offshore sediment from Seattle South Waterfront problem area and a nearby drain.

or historical CSOs. For example, high concentrations of several chemicals were found in the sediments at Station SS-09, which was not located near a CSO outfall (see Figure 4-10). With no other point sources in the area, the widespread chemical contamination in Seattle South Waterfront sediments may have been from sources other than the drains in the area or historical sources.

Other Potential Sources--Contaminants may also be transported to offshore sediments through groundwater flow, atmospheric deposition, and accidental spills. The Seattle South Waterfront problem area, though highly contaminated, is the most difficult area to evaluate potential sources. Although the widespread contamination in the offshore sediments suggests a large number of industrial and/or municipal chemical sources, there are few industrial facilities in the area. Land use in the vicinity of the Seattle South Waterfront is presently dominated by service industries, offices, and retail businesses.

The lack of industrial sources is reflected in the relatively small number of discharge permits issued to industries in the area. Only five facilities have Metro industrial pretreatment permits (Hildebrand, D., 16 October 1987, personal communication). All of the facilities are allowed to discharge low levels of cadmium, chromium, copper, nickel, lead, and zinc into the Metro sewer system. Two NPDES permits for the discharge of noncontact cooling water containing zinc have been issued to steam production facilities. Potential industrial sources included on the U.S. EPA Region X CERCLIS include a metal finisher, a newspaper, and a research and development laboratory that in the past stored hazardous waste (U.S. EPA, 22 October 1987, personal communication).

Current facilities located directly on the waterfront include the Washington State Ferry Terminal (Coleman Dock) and the Alaska Ferry System Terminal, and BC Steamship Ferry Terminal. Although the central waterfront is no longer a shipping center, ships are occasionally moored at various piers in this area and can be transient sources of contamination. Ecology (1987) has conducted periodic inspections of some of these ships. In May 1987, Ecology inspected the Emerald Sea, a ship that was docked at Pier 54.

The ship was being sanded in preparation for painting, and minor repairs were also being conducted. Contaminants such as enamel paint chips, aluminum chips, and particles were falling into the water. Similar paintscraping, rust removal, and paint applications are routinely conducted while ships are in port. Copper, lead, mercury, and zinc are among the contaminants associated with marine paints (Muehling 1987). Accidental spills of oil and fuel from these ships can contribute to PAH contamination.

The absence of heavy industry on the Seattle South Waterfront is not typical of historical land use. For at least half a century, this area was a center for shipbuilding, commerce, and transit. Because of sediment turnover and biological mixing, present contamination in offshore sediments may also reflect historical contamination. For example, there are many historical sources of PAH contamination in the Seattle area, including wood fires (e.g., the 1889 fire that destroyed 50 city blocks), coal, and creosote. Coal was major part of early Seattle's economy. Coal bunkers were located at the foot of Dearborn, King, Washington, and Pike Sts. In 1887, the Pike St. coal bunker collapsed, depositing coal directly into Elliott Bay (Dorpat 1984). In addition, many fish canneries were formerly located along the Seattle waterfront. Historical discharges of cannery process water and other activities associated with this industry may have contributed to metal contamination observed in this area.

Prior to 1969, raw sewage discharges entered the Seattle South Waterfront area via nine outfalls (Metropolitan Engineers 1970). Two additional outfalls that discharged raw sewage were located just north of Seattle South Waterfront problem area. After this time, sewage was routed via the Elliott Bay interceptor system to the West Point wastewater treatment plant. The importance of these historical discharges in contributing to the contamination observed recently in offshore sediments in the Seattle South Waterfront problem area is unknown.

Past activities related to shipping may also have contributed to offshore contamination. Ship ballast and waste were discarded wherever ships docked. Warehouses and docks extended along the shoreline as far north as Wall St. Creosote, used as a wood preservative on pilings and

docks, can be a major source of PAH contamination in the marine environment (Krone et al. 1986).

Another past source of contamination may have been the shipbuilding industry located along the central waterfront that was active from approximately 1870 to 1920. Construction of wooden ships involved a variety of local firms that could have been sources of metal contamination (e.g., brass and iron foundries, machine shops, and boiler shops). Coal tar was used to fill voids inside ships and was spread over hulls as a protective coating, potentially causing PAH contamination (Krone et al. 1986). The Moran yard, located near today's Terminal 46 at the foot of King St. (see Figure 4-5), was one of the first yards constructing steel-hulled vessels. This and similar operations may have been major contributors to past metal contamination.

The degree of contamination from historical sources is impossible to quantify. For purposes of source control, the ongoing sources must be evaluated. The most probable ongoing sources of contamination in Elliott Bay are the CSO/SDs and the diffuse input from the multiple sources associated with urban environments. Pollutant loading from urban runoff, which depends on local land use, traffic volume, road surface type, and rainfall, can be difficult to assess and may range by 2 orders of magnitude (Curl et al. 1987). Urban street dust containing both metals and LPAH is a major contributor of contaminants to stormwater runoff. Chromium, copper, lead, and zinc, all identified as problem chemicals in Seattle South Waterfront sediments (PTI and Tetra Tech 1988), are major components of street dust (Galvin and Moore 1982). LPAH compounds, particularly anthracene and phenanthrene, are also frequently detected in urban street dust. Galvin and Moore (1982) reported that phenanthrene was detected in 100 percent of street dust samples at concentrations ranging from 180-2,400 ug/kg; anthracene was detected in 36 percent of the Elliott Bay Action Program samples, at concentrations ranging from 100-600 ug/kg. Both compounds were observed in all offshore samples. Comparison of relative distributions of PAH compounds indicated that street dust was a major contributor to sediment contamination in the Vine CSO, and therefore contributed to PAH and metal contamination in Elliott Bay sediments.

Summary--

The extreme chemical contamination observed in offshore sediments in the Seattle South Waterfront problem area derives from both historical and ongoing sources. Decades of untreated sewage and industrial discharge have contributed to the contamination observed in this area. Current sources include the CSOs and storm drains, which transport urban runoff (e.g., street dust), as well as both permanent and transient waterfront sources of contamination (e.g., creosote pilings, accidental oil spills, and ship discharge). Few industrial facilities are located in the area, and none were identified as substantial ongoing sources of contamination.

5.1.2 North Harbor Island I Problem Area

The boundaries of North Harbor Island I problem area extend from Pier 17 on the north end of Harbor Island, west past Craneway Pier 3, which is located west of the West Waterway (see Figure 4-10). Two shipyard facilities, several bulk petroleum storage facilities, and a marine vessel tugboat operation are located adjacent to the problem area. The 11th Ave. CSO/SD (077) serves the northeast corner of the problem area, and discharges off the north end of Harbor Island near Pier 17 (see Figure 4-10). The 11th Ave. CSO/SD is the only city CSO/SD that discharges into the problem area. However, there are numerous private storm drains serving the north end of Harbor Island and West Seattle that discharge into North Harbor Island I problem area (see Figure 4-10).

North Harbor Island I problem area ranked among the highest priority areas based on both chemical contamination and biological effects (PTI and Tetra Tech 1988). The area was characterized by very high concentrations of several metals (arsenic, copper, mercury, lead, and zinc), PAHs, and PCBs. Chemical contaminants that exceeded HAET in offshore sediments from at least one station in this area included copper, lead, zinc, mercury, arsenic, LPAH, HPAH, PCBs, p,p'-DDD, 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol (Table 5-2). Generally, the highest concentrations of copper, mercury, zinc, LPAH, HPAH, and PCBs in the problem area were measured at stations

TABLE 5-2. HAET and LAET EXCEEDANCES IN THE NORTH HARBOR ISLAND PROBLEM AREAS^a

Area	Station	HAET Exceedances ^b											LAET Exceedances ^c
		LPAH	HPAH	PCBs	CU	PB	ZN	HG	AS	p,p'-DDD	4MEPHNL	2MEPHNL/ 2,4MEPHNL	
North Harbor Island I	NH-01												HPAH, PCBs
	NH-02												HPAH, PCBs, HG
	GAMP1 ^d			X								X	HPAH, HG
	E36 ^e	X	X										
	GAMP2 ^d											X	AS, HPAH, CU, PB, HG, ZN, PCBs
	E37 ^e	X	X			X							ZN
	GAMP3 ^d	X	X	X	X		X	X				X	AS
	E4 ^e	X	X	X	X		X						AS
	NH-03	X	X	X	X			X		X			AS, BUTBNZPH, PB, ZN [TOTXYL]
	E39 ^e		X		X								LPAH, PCBs, ZN
	WW-19				X							X	ZN, HG, PCBs, HPAH
	E40 ^e	X											HPAH, ZN
	GAMP4 ^d			X									AS, HG, ZN
	WW-20 (West Waterway Mouth)												HPAH, HG, PCBs
North Harbor Island II	GAMP5 ^d											X	LPAH, HPAH, PCBs, HG
	E41 ^e												HPAH
	GAMP6 ^d			X								X	AS, HPAH, LPAH, PCBs, HG, ZN
	E42 ^e			X	X	X	X		X				HPAH, LPAH
	NH-04	X	X		X							X	AS, PB, HG, ZN, 4MEPHNL, PCBs [PCP, PHNL]
	NH-05	X											HPAH, HG, PCBs, ZN
	GAMP7 ^d	X	X	X									HG
	E43 ^e	X	X										ZN
	U120 ^f	X											PCBs, ZN
	NH-06	X	X										HG, PCBs, ZN [CARBAZOLE, CD]
North Harbor Island II	NH-08	X	X										PCBs, ZN
	GAMP8 ^d											X	LPAH, HPAH, PCBs
	E44 ^e	X	X										ZN
	S0034 ^g		X	X									HG, LPAH
NH-10													PCBs [ALDRIN, DIELDRIN]

^a LPAH - Signifies AET exceedances for the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene, or any of these compounds individually. To simplify the presentation of AET exceedances in this table, exceedances of AET for 1-methylphenanthrene, 2-methylnaphthalene, biphenyl, and dibenzofuran are included under LPAH. These compounds covaried with LPAH but are not included in LPAH sums.

HPAH - Signifies AET exceedances for the sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene, or of any of these compounds individually.

CU - copper
PB - lead
ZN - zinc
HG - mercury
CD - cadmium

BNZOH - benzyl alcohol
BNZACID - benzoic acid
1,4DICLBZ - 1,4-dichlorobenzene
BUTBNZPH - butyl benzyl phthalate
DMP - dimethyl phthalate

TABLE 5-2. (Continued)

AG - silver
 AS - arsenic
 PHNL - phenol
 4MEPHNL - 4-methylphenol
 2MEPHNL - 2-methylphenol
 2,4MEPHNL - 2,4-dimethylphenol

TOC - total organic carbon
 DINOCT - di-n-octyl phthalate
 TOTXYLENE - total xylenes
 CR - chromium
 ENDALD - endrin aldehyde
 PCP - pentachlorophenol

^b Chemicals exceeding HAET for Puget Sound.

^c Chemicals exceeding LAET for Puget Sound. Chemicals shown in brackets exceeded 90th-percentile concentrations but did not exceed any AET. Chemicals exceeding both AET and 90th-percentile concentrations are not bracketed.

^d Gamponia et al. (1986).

^e U.S. EPA (1982, 1983).

^f Stober and Chew (1984).

^g Romberg et al. (1984).

Reference: PTI and Tetra Tech (1988).

between Piers 13 and 14 offshore of Harbor Island and stations between Craneway Piers 2 and 3 offshore of West Seattle (see Figure 4-10). Both of these two highly contaminated areas are located offshore of shipyard facilities. Lower concentrations of most problem chemicals occurred at the mouth of the West Waterway, which suggests that there were separate sources contributing to the contamination offshore of Harbor Island and West Seattle.

Arsenic concentrations were not highly elevated in the North Harbor Island I problem area, although the arsenic concentration (1,420 mg/kg) at historical Station E42 (U.S. EPA 1982, 1983), located in the mouth of the West Waterway just east of Craneway Pier 1 (see Figure 4-10) exceeded the arsenic HAET (700 ug/kg). The next highest arsenic concentration in the problem area was measured at historical Station 5 (Gamponia et al. 1986), which was centrally located at the mouth of the West Waterway. Arsenic concentrations at six additional stations in the area (Stations 2, 3, 4, 6, Gamponia et al. 1986; Stations NH-03 and NH-04) exceeded the LAET for arsenic (85 mg/kg). Three of the six stations (Station 3, Gamponia et al. 1986; Station E42, U.S. EPA 1982, 1983; Station NH-03, and Station NH-04) were located adjacent to shipyard drydocks. Historical Station 3 (Gamponia et al. 1986) was located between the railcar loading pier and Pier 14, adjacent to a drydock. Station NH-03 was located adjacent to the drydock between Pier 13 and the railcar loading pier. Station NH-04 was located adjacent to a drydock on the west side of the West Waterway between Craneway Piers 1 and 2 (see Figure 4-10). Two of the six stations (Stations 4 and 6, Gamponia et al. 1986) were located at the mouth of the West Waterway near shipyard facilities; and historical Station 2 (Gamponia et al. 1986) was located offshore from the north end of Harbor Island between Piers 14 and 15. The relative abundance of arsenic at Stations NH-03, NH-04, WW-19, 5, E5, E41, and WW-20 ranged from 2 to 7 percent (Figure 5-5). Station WW-19 was located in a shipyard slip just south of the northwest corner of Harbor Island. Stations 5, E5, E41, and WW-20 were all centrally located in the mouth of the West Waterway. Because the relative arsenic contribution did not vary substantially between the stations evaluated, the sources of arsenic in the problem area may not have been localized.

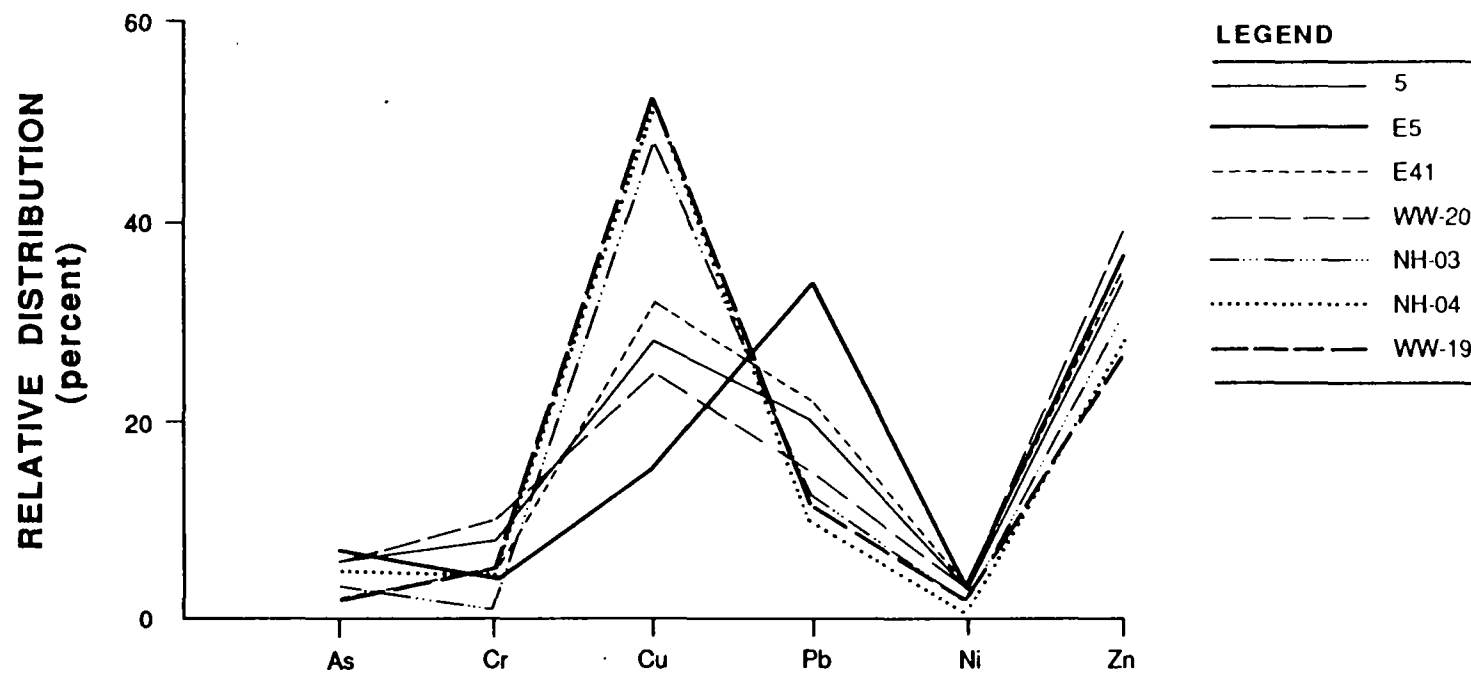


Figure 5-5. Comparison of relative percent distribution of metals in sediments adjacent to shipyard facilities and sediments from selected stations in the center of the West Waterway.

The copper HAET (800 ug/kg) was exceeded at seven stations in the North Harbor Island I problem area (see Table 5-2) (PTI and Tetra Tech 1988). Copper concentrations were most elevated (1,220-2,820 mg/kg) at stations located adjacent to shipyard facilities and tended to decrease with distance from the mouth of the waterway. The highest copper concentrations in the PTI and Tetra Tech (1988) study were measured at Stations NH-03 (2,050 mg/kg), NH-04 (1,770 mg/kg), and WW-19 (1,300 mg/kg). Station WW-19 had the highest copper concentration in the West Waterway based on a dry-weight or percent-fines normalization, and was therefore included in the North Harbor Island I problem area (PTI and Tetra Tech 1988). In addition, historical Stations E4, E39, E42 (U.S. EPA 1982, 1983), and 3 (Gamponia et al. 1986) had copper concentrations greater than 1,000 mg/kg. These historical stations were all located adjacent to shipyard facilities (see Figure 4-10).

The relative abundance of copper at Stations NH-03, NH-04, and WW-19 ranged from 49 to 52 percent (see Figure 5-5). In contrast, the relative abundance of copper at Stations 5, E5, E41, and WW-20, which were located in the center of the West Waterway, ranged from 15 to 32 percent. This suggests that local contaminants were likely the primary source of copper at Stations NH-03, NH-04, and WW-19.

Historical Stations E42 and E37 (U.S. EPA 1982, 1983) were the only stations in the problem area that exceeded the HAET for lead (700 mg/kg). Station E42, located in the mouth of the West Waterway adjacent to a shipyard, exhibited 2,180 mg/kg of lead. A nearby station (Station 6, Gamponia et al. 1986) exhibited substantially lower concentrations of lead (235 mg/kg). Station E37 was located offshore from the north end of Harbor Island just east of Pier 15. Lead concentrations exceeded the LAET at three additional stations (Stations NH-03, NH-04, and 2), although there were no apparent concentration gradients (PTI and Tetra Tech 1988). The relative abundance of lead at Stations NH-03, NH-04, and WW-19 ranged from 10 to 13 percent (see Figure 5-5). The relative abundance of lead at Stations 5, E5, E41, and WW-20 was somewhat higher with values ranging from 15 to 34 percent (see Figure 5-5). The higher range of lead concentrations at stations adjacent to shipyards than the lead concentrations observed at

stations in the West Waterway channel suggests that local contaminant sources were contributing to the lead contamination in the sediments in the North Harbor Island I problem area.

The HAET for mercury (2.1 mg/kg) was exceeded at two stations in the North Harbor Island I problem area. A mercury concentration of E10.5 mg/kg was reported at Station NH-03; however, the mercury concentration (0.85 mg/kg) measured at adjacent Station E39 was 10 times lower on a dry-weight or percent-fines normalized basis. A high mercury concentration (12 mg/kg) was reported at Historical Station 3 (Gamponia et al. 1986), located between the Todd Shipyards drydock and Pier 14. Fourteen other stations in the problem area had mercury concentrations greater than the mercury LAET (0.41 mg/kg) (see Table 5-2).

The HAET for zinc (1,600 mg/kg) was exceeded at three historical stations (Stations E4 and E42, U.S. EPA 1982, 1983; and Station 3, Gamponia et al. 1986) in the problem area (see Figure 4-10). Generally, higher concentrations of zinc were exhibited at stations adjacent to the shipyards. Historical Stations E4 and 3 were both located approximately 100 yd offshore from the north end of Harbor Island between the railcar loading pier and Pier 14. Historical Station E42 was located in the mouth of the West Waterway east of Craneway Pier 1 and had the highest zinc concentration (4,810 mg/kg) in the North Harbor Island I problem area.

The HAET (6,100 ug/kg) for LPAH was exceeded at seven stations (Stations E4, 3, NH-03, NH-04, E40, E37, and E36) in the North Harbor Island I problem area (PTI and Tetra Tech 1988). The most severe LPAH contamination in the problem area occurred at Stations E4 (130,000 ug/kg; U.S. EPA 1983) and Station 3 (25,000 ug/kg; Gamponia et al. 1986) located between the railcar pier and Pier 14 offshore of Harbor Island (see Figure 4-10). Although the most highly elevated LPAH concentrations occurred near shipyard drydocks, LPAH levels at Station E37 (12,000 ug/kg; U.S. EPA 1983) and Station E36 (9,800 ug/kg; U.S. EPA 1983) exceeded the HAET as well. Station E37 was located offshore from the north end of Harbor Island between Piers 14 and 15, and Station E36 was located nearby between Piers 15 and 17 (see Figure 4-10).

HPAH concentrations were elevated throughout the North Harbor Island I problem area and exceeded an AET at every station evaluated (see Table 5-2) (PTI and Tetra Tech 1988). A total of seven stations (Stations E4, 3, NH-03, NH-04, E37, E36, and E39) in the North Harbor Island I problem area exceeded the HAET (38,000 ug/kg) for HPAH (PTI and Tetra Tech 1988). As was the case for LPAH, the most severe HPAH contamination occurred off the northwest corner of Harbor Island at Station E4 (U.S. EPA 1983), where an HPAH concentration of 450,000 ug/kg (U.S. EPA 1983) was observed. The next highest HPAH concentration (110,000 ug/kg) was measured at adjacent Station 3 (Gamponia et al. 1986), and thus supported the high concentration observed at Station E4. Generally, the HPAH contamination decreased moving east from the drydock area, but the HAET for HPAH was exceeded at Stations E37 and E36.

PCB contamination in the North Harbor Island I problem area was elevated, but a distribution gradient was not apparent (PTI and Tetra Tech 1988). The HAET for PCBs (2,500 ug/kg) was exceeded at seven stations (Stations 1, 3, E4, NH-03, 4, 6, and E42) in the problem area (see Table 5-2). Station 3 (Gamponia et al. 1986) exhibited a PCB concentration of 14,000 ug/kg, which was the highest concentration observed in the North Harbor Island I problem area. A PCB concentration of 3,800 ug/kg was measured at adjacent Station E4 (U.S. EPA 1983). In addition, Gamponia et al. (1986) Station 1 (see Figure 4-10) had a PCB concentration of 7,500 ug/kg. Interpretation of historical PCB data was impeded to some extent by high detection limits (PTI and Tetra Tech 1988).

Station WW-19 was the only station in the problem area that exceeded the HAET (1,200 ug/kg) for 4-methylphenol (2,600 ug/kg), and exceeded EAR by a factor of 200. A moderate 4-methylphenol concentration (1,000 ug/kg) was measured at Station NH-04. Although an HAET for pentachlorophenol does not exist, it is noteworthy that the maximum pentachlorophenol concentration (6,000 ug/kg) measured in the PTI and Tetra Tech (1988) study occurred at Station NH-04.

The HAET (43 ug/kg) for p,p'-DDD was exceeded at only one station in the problem area, Station NH-03, where a relatively high concentration (120 ug/kg) was observed. PCB concentrations were generally elevated at stations where high pesticide concentrations were measured. However, it is possible that PCBs interfered with the analysis of pesticides and may have artificially increased the pesticide concentrations (PTI and Tetra Tech 1988).

Potential Contaminant Sources--

11th Ave. SW CSO/SD (077)--The 11th Ave. SW CSO/SD (077) drains a 37-ac area in the northeast corner of Harbor Island (see Map 3 in Map Appendix), and is the only city CSO/SD discharging into the North Harbor Island I problem area. The 11th Ave. SW CSO/SD also serves as an emergency overflow for a pump station on the sanitary sewer system on Harbor Island, and receives NPDES-permitted surface runoff from bulk petroleum facilities in the drainage basin. Cadmium, lead, and HPAH were identified as problem chemicals in the sediment collected from the CSO/SD. One offshore sediment station (NH-01) was located near the outfall of the 11th Ave. SW CSO/SD (077); however, no chemicals exceeding an HAET were identified in the sediment collected at the station. Therefore, although the sediment in the 11th Ave. SW was contaminated, a corresponding level of contamination was not measured in the offshore sediments. Only HPAH, which exceeded LAET in the offshore sediments, corresponded with the contamination found in the drain sediments.

A comparison of the relative abundances of HPAH compounds in sediments from the 11th Ave. SW CSO/SD (077) and nearby offshore sediment Station NH-01 is shown in Figure 5-6. Fluoranthene was the predominant HPAH compound found in the 11th Ave. SW CSO/SD (077), constituting 30 percent of the total HPAH compounds. The offshore sediment at Station NH-01 contained a higher percentage of total benzofluoranthenes (30 percent) than the 11th Ave. SW CSO/SD (077) sediment (13 percent). Because of the differences in the relative abundances of HPAH compounds observed in the 11th Ave. SW CSO/SD (077) and Station NH-01, a link between the drain and receiving environment could not be demonstrated at the time of sample collection.

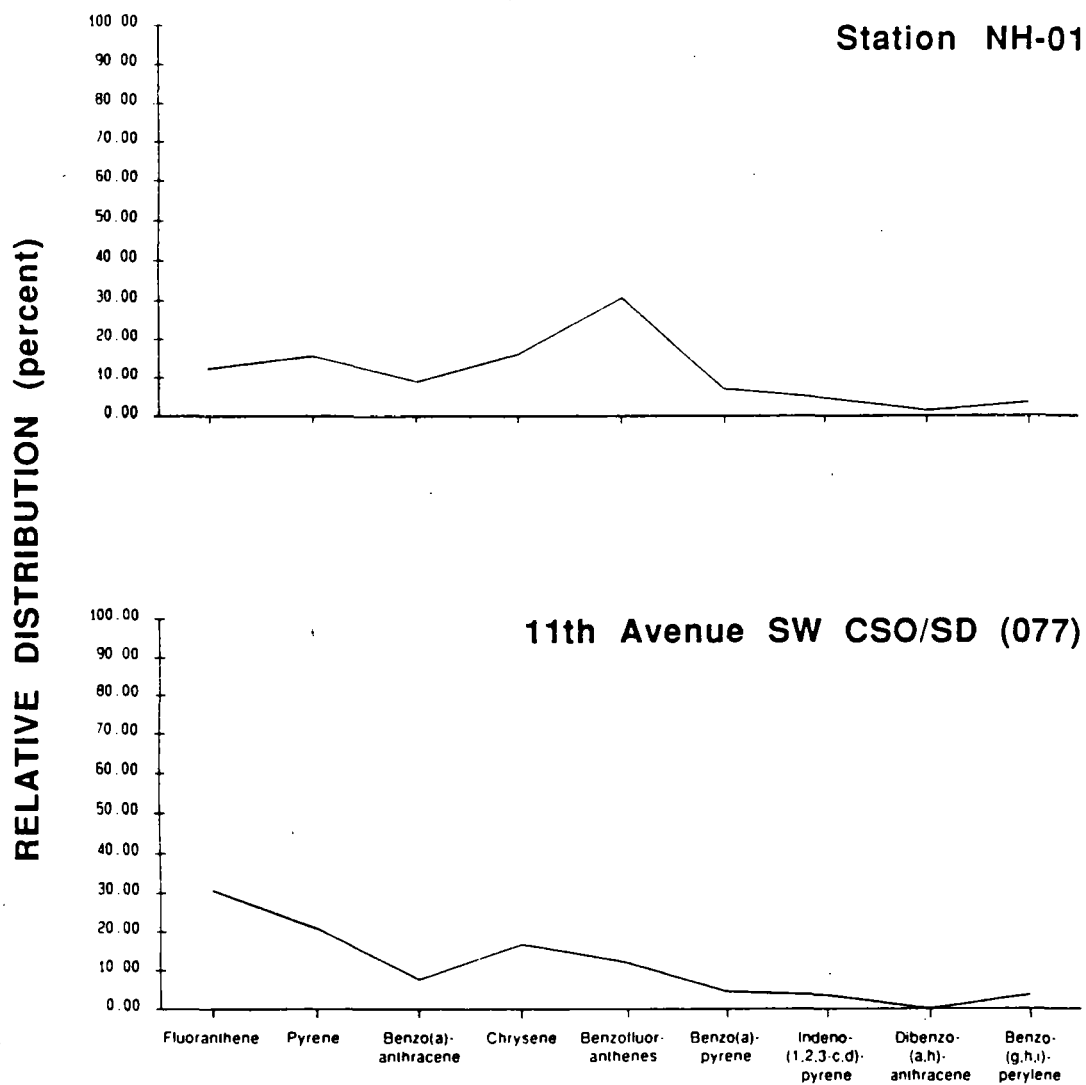


Figure 5-6. Comparison of relative percent distribution of HPAH in offshore sediment from North Harbor Island I problem area and a nearby drain.

Private Storm Drains--Most of the waterfront property in problem area North Harbor Island I is served by private storm drains (see Figure 4-10). Relatively little is known about the origin and type of discharges from these private drains. Discharges from the private drains are expected to be relatively low, because they serve only the associated industrial facilities. However, based on the sediment data obtained from other storm drains in the project area, it is possible that these drains may contribute contaminants to the nearshore environment. In particular, lead has been identified as a problem chemical in many of the storm drains serving Harbor Island, and has been associated with historic emissions from the secondary lead smelter that operated there between 1937 and 1984.

Todd Shipyards--Todd Shipyards has operated a shipbuilding and repair business on Harbor Island since approximately 1918. Prior to 1952, Todd functioned exclusively as a ship repair facility. Todd began building ships in 1952. Several offshore stations (Station NH-03; Station E4, U.S. EPA 1983; and Station 3, Gamponia et al. 1986), located adjacent to the Todd Shipyard drydocks (see Figure 4-10), exhibited the highest concentrations and observed in the North Harbor Island I problem area. Several contaminants (i.e., copper, mercury, and PCBs) exceeded HAET concentrations at these stations.

Elevated concentrations of copper, have been found in sediments collected near shipyard drydocks where sandblasting occurs and paints may be spilled (Bellinger and Benham 1978). The relative distributions of selected metals in the sediments adjacent to the Todd facility (Stations NH-03 and WW-19) are compared to the distributions found in sediments collected from the middle of the West Waterway (historical Stations E5, E41, and 5) in Figure 5-5. Sediments immediately offshore of the Todd facility contained a greater abundance of copper (49-54 percent) than the West Waterway stations (13-32 percent). In addition, the concentrations of copper in the sediments collected near the drydock facilities (1,680-2,820 mg/kg) were 14-50 times greater than the concentrations observed in the West Waterway (54-124 mg/kg). This difference indicates that the shipyard was a

major potential source of copper contamination observed in the offshore sediments.

Sandblasting operations are the major source of copper associated with shipbuilding and repair facilities. It has been reported that shipyards in the project area have used slag containing roughly 1 percent copper by weight for sandblasting material from a copper smelter in British Columbia (Dexter et al. 1981). In addition, copper is one of the primary constituents in marine paints currently used in the shipping industry (Bellinger and Benham 1978). Copper, zinc, and prior to 1975, mercury, have been used as antifoulant agents in marine paints (Muehling 1987). The concentrations of mercury and zinc also exceeded HAET at the stations [Station NH-03 (mercury), Station 3 (mercury and zinc; Gamponia et al. 1986), and Station E4 (zinc; U.S. EPA 1983)] adjacent to the Todd facility. Prior to repainting, antifoulant paints are generally removed from the hull of the ship during sandblasting (Bellinger and Benham 1978). In the past, it was common practice for shipyards to dispose of spent sandblast grit directly into the waterways. Copper, mercury, and zinc were deposited along with the sandblasting grit in the offshore sediments. However, Ecology has recently required that shipyards in the Puget Sound area control the release of sandblasting materials to the waterways (Morrison, S., 25 August 1987, personal communication).

Lead is also used in marine paints to inhibit corrosion. However, anticorrosive and primer paints, which are applied to the hull first, are removed only during a rigorous surface preparation (Bellinger and Benham 1978). Lead did not exceed the HAET at any stations along the drydock area.

The recent implementation of best management practices at Todd Shipyards is expected to substantially reduce the contamination of the offshore sediments caused by sandblasting operations. In 1983, Todd built a new sandblasting facility to contain sandblasting materials (Cargill, D., 27 April 1988, personal communication). In addition, Todd Shipyards also temporarily discontinued using copper slag as sandblast grit. However, in 1987, it was documented that Todd Shipyards was using copper slag to sandblast ship exteriors and steel shot to sandblast the interiors of ships

(Ecology 1987). Since 1985, Todd has reduced the release of sandblast materials from external ship sandblasting activities by installing tarps around and under the work area. In addition, spent sandblast grit is now removed from the drydocks with front-end loaders prior to flooding the drydock (Ecology 1987). Spent grit that is not removed by the front-end loaders is swept up with a broom. The metals contamination observed offshore of the Todd Shipyard facility may have been related to historical rather than ongoing practices.

The mercury contamination in the sediments offshore of Todd Shipyards (Stations 3, Gamponia et al. 1986; and Station NH-03) may have been related to sandblasting operations, because the distribution of mercury in the offshore sediments was similar to the distribution of copper. Prior to 1975, various mercury compounds were often used as antifoulants (Muehling 1987). In addition, manometers containing mercury are frequently used to show the level of liquids in tanks and vessels (Perry and Greene 1984). Manometers containing mercury at the Todd facility are currently set in metal trays to contain any spills, and the mercury is reportedly disposed of properly (Ecology 1987). Therefore, it is unlikely that the Todd facility is a major ongoing source of mercury.

The distribution of PAH in the offshore sediments was also similar to the distribution of copper, which suggests that the contamination may have been associated with shipyard activities. The highest concentrations of PAH (132,000-632,000 ug/kg) occurred at Stations 3, E4, and NH-03, which were located adjacent to the Todd drydocks (see Figure 4-10). With the exception of Station E37, PAH concentrations at nearby stations in the West Waterway and east of the Todd facility were lower (5,900-49,000 ug/kg) than the stations offshore of the Todd facility. The elevated PAH concentration observed at Station E37 (101,000 ug/kg; U.S. EPA 1983) is not supported by data collected by Gamponia et al. (1986) at nearby Station 2 (25,000 ug/kg). PAH contamination at this station may have been associated with activities at the Mobil Oil pier, and is discussed in a later section.

Solvents (including paint and lacquer thinner), acids, caustics, oils, oil/water mixtures, and paints are identified in an Annual Generator

Dangerous Waste Report as wastes generated at the Todd Shipyard facility (Ecology 1987). Heavy duty marine coatings, including primers/anticorrosives (containing lead chromates and coal tar derivatives), antifoulants high in copper content, and oil-based, alkyd-type finishing enamels have historically been used at the site (Cargill, D., 27 April 1988, personal communication). Past spills of these materials are the most likely pathway to Elliott Bay. However, insufficient information was available to confirm that Todd Shipyard contributed to the contamination observed in the offshore sediments.

Historically, the use of sodium arsenite on shipyard drydocks was a substantial source of arsenic to the waterways. However, Ecology no longer permits the use sodium arsenite. Prior to 1975, Todd Shipyards treated each of their two drydocks twice a year with sodium arsenite to control woodworms (Tetra Tech 1986b). The arsenic concentrations measured at stations adjacent to the Todd facility (Stations E4, 3, and WW-19) and in the drydocks (Stations E39 and NH-03) ranged from 18 to 268 mg/kg, but did not exceed the HAET for arsenic (700 mg/kg).

The highest concentration of 4-methylphenol (2,600 ug/kg) observed in the North Harbor Island I problem area was measured at Station WW-19, located in a Todd Shipyard slip south of the northwest corner of Harbor Island. This concentration exceeded the HAET for 4-methylphenol (1,200 ug/kg). No specific uses of 4-methylphenol at Todd Shipyards have been identified.

Prior to 1977, PCBs were used extensively in transformers, fluorescent light ballasts, and some types of capacitors/starters. Production of PCBs was halted in 1977, and their use and disposal is now regulated by the U.S. EPA. Most transformers on Harbor Island containing PCBs have been replaced in recent years. PCB concentrations at stations adjacent to Todd Shipyards (including Stations NH-03; and E4, U.S. EPA 1982, 1983), and Station 3, Gamponia et al. 1986) ranged from 3,300 to 14,000 ug/kg and exceeded the HAET for PCBs. However, PCB contamination throughout the North Harbor Island I problem area was elevated and concentrations exceeded an AET at all but four stations (Stations E36, E37, E40, and E41) (see Table 5-2) (PTI and Tetra Tech 1988).

No specific uses of p,p'-DDD have been documented at the Todd Shipyard facility. The highest p,p'-DDD concentration (120 ug/kg) observed in the North Harbor Island I problem area occurred at Station NH-03, which was located in the Todd Shipyard drydock east of Pier 13 (PTI and Tetra Tech 1988).

Lockheed Shipbuilding Company--Lockheed is located on the west side of the West Waterway. Lockheed constructs, repairs, and maintains ocean-going vessels. Therefore, activities such as steel/hull repair, machining, sandblasting, and painting are likely to take place at this site. Materials that may be encountered in the shipbuilding business include paint, blasting grits, solvents, asbestos (sometimes removed during the refurbishment of older ships), sodium arsenite (to protect shipyard drydocks from woodworms), and launching grease.

The distribution of contaminants offshore of the Lockheed facility was similar to the distribution of contaminants offshore of Todd Shipyards (see Table 5-2). HAETs for metals (i.e., copper, lead, and zinc), PAH, and PCBs were exceeded at stations adjacent to Lockheed's drydock facilities (Station NH-04; Station E42, U.S. EPA 1983; and Station 6, Gamponia et al. 1986) (see Figure 4-10). However, lower concentrations of these contaminants were observed at stations located offshore of the mouth of the West Waterway (Station WW-20; Stations 4 and 5, Gamponia et al. 1986; Stations E5 and E41, U.S. EPA 1983), indicating that contamination observed offshore of the Lockheed drydocks was potentially caused by operations at Lockheed.

Like Todd Shipyards, the Lockheed property is also served by private storm drains (see Figure 4-10). These drains serve relatively small areas, and although they may contribute to the contamination observed in the offshore sediments, they were probably not the major source of contamination. Past sandblasting activities were the most likely source of metals contamination in the offshore sediments. The relative distribution of metals in the sediment adjacent to the Lockheed facility (Station NH-04) was compared to the distributions found in sediments collected off of the mouth of the West Waterway (Stations E5 and E41, U.S. EPA 1983; WW-20; and Station 5, Gamponia et al. 1986) (see Figure 5-5). The sediment sample collected adjacent to the

Lockheed drydock (Station NH-04) contained a greater abundance of copper (50 percent) than the sediment from the West Waterway Stations E5, E41, and E42 (U.S. EPA 1983), WW-20, and 6 (Gamponia et al. 1986) (11-30 percent copper). In addition, the concentration of copper in the sediment collected near the drydock facility (1,770 mg/kg) was greater than the concentrations observed in the nearby sediment samples (97-1,050 mg/kg), indicating that the shipyard was potentially a source of the copper contamination observed in the offshore sediments.

As was explained above, past sandblasting operations were the most likely source of copper and other metals (i.e., lead, zinc, and mercury) from shipyards. The release of sandblasting materials from shipyards is now regulated under the new NPDES-permit requirements. Implementation of best management practices under the NPDES-permit program is expected to reduce the release of sandblasting materials from shipyards. Therefore, the contamination observed offshore of the Lockheed facility at Station NH-04 was probably related to historical rather than ongoing practices.

No specific sources of PAH have been linked to the contamination observed at Station NH-04, which is adjacent to the Lockheed drydock (see Figure 4-10). PAH contamination may have been caused by past spills from ship repair activities. Although, the PAH contamination observed at Station NH-04 (E32,600 ug/kg) was greater than the concentrations observed at nearby stations (4,200-18,000 ug/kg), the spatial coverage in this area and available information on waterfront activities is insufficient to determine whether the Lockheed facility was the major PAH source in this area.

Mobil Oil--A Mobil Oil lubricant oil storage facility has been located on north Harbor Island waterfront property since approximately 1966. Currently, a lubricant-oil, truck-loading rack and four small aboveground storage tanks used to store bulk lubricating oils are located in a bermed gravel area at the site. However, the property has been the site of petroleum-related operations since as early as 1920 and is considered to be a potential source of PAH compounds to the nearby offshore sediments in the North Harbor Island I problem area.

Mobil Oil currently discharges stormwater runoff under an NPDES permit (see Table 2-4), and is served by the 11th Ave. SW CSO/SD (077). In addition, available storm drain maps indicate that several private storm drains exist on Mobil property. The HAET for HPAH was exceeded in the sediment collected in the 11th Ave. SW CSO/SD (077), as well as in the offshore sediments collected from historical Stations E36 and E37 (U.S. EPA 1982, 1983). Stations E36 and E37 were located on the east and west sides of Pier 15, respectively. However, sediments collected from historical Stations 1 and 2 (Gamponia et al. 1986), which were located adjacent to Stations E36 and E37, did not exceed the HAET for HPAH. Sediments from Station NH-02 (located nearest to the Mobil Oil property than any other sampling station), and Station NH-01 [located near the 11th Ave. SW CSO/SD (077)] did not exceed the HAET for any compound, although the LAET for HPAH was exceeded at both stations.

The HAET (29 ug/kg) for 2,4-dimethylphenol was exceeded at historical Stations 1 and 2 (Gamponia et al. 1986). The 2,4-dimethylphenol concentrations at Stations 1 and 2 were 450 and 800 ug/kg, respectively. 2,4-Dimethylphenol was undetected at adjacent Stations E36 and E37. No specific use of 2,4-dimethylphenol at the Mobil facility has been documented.

Accidental spills of oils and fuels from bulk petroleum storage facilities are potential sources of PAH compounds. Several small spills (less than 30 gal) of diesel fuel and oil from vessels and/or barges are known to have occurred at the Mobil Oil fuel dock and may have contributed to the PAH contamination observed in the offshore sediments. In addition, leaded tank bottoms, from the storage of leaded gasoline, are likely to have been generated at the site. Landfarming of tank bottom sludge (a potential source of lead) on Harbor Island has been practiced in the past. Information on landfarming on Mobil property has not been documented.

Other Potential Sources--Industries that conduct their operations on waterfront property in the North Harbor Island I problem area, but due to the nature of their operations are not considered to be primary sources of contaminant input to Elliott Bay or the 11th Ave. SW CSO/SD (077), include

a marine tugboat operator, a common carrier railroad, and a railcar transshipment facility.

Summary--

Problem area North Harbor Island I ranked among the highest priority problem areas in the project area based on both chemistry and biological effects (PTI and Tetra Tech 1988). The area was characterized by very high concentrations of several metals (i.e., arsenic, copper, mercury, lead, and zinc), PAHs, and PCBs. Several of the problem metals (i.e., copper, lead, and zinc) are commonly associated with historical shipyard operations. Two shipyard facilities adjacent to Elliott Bay and the West Waterway (i.e., the Todd and Lockheed shipyards) were considered to be potential sources of metals because of distributions of metals in offshore sediments and the shipyard's association with sandblasting activities. In addition, the distribution of PAHs in nearby offshore sediments suggest that the shipyards are potential sources, although there are no documented discharges of PAHs at these facilities. Furthermore, a bulk petroleum storage facility located on the north end of Harbor Island was considered to be a potential source of PAH compounds to this problem area. The source of PCBs could not be identified, although PCBs were widely used historically in transformers, hydraulic fluids, and light ballasts.

5.1.3 North Harbor Island II Problem Area

The boundaries of problem area North Harbor Island II extended east from historical Station U117 (Stober and Chew 1984) to Station NH-05, that was located west of the mouth of West Waterway just offshore from the Lockheed shipyard facility (see Figure 5-1). The shoreline along this section of West Seattle has undergone considerable change in the last 25 yr. Aerial photographs from 1963 show that much of the area south of SW Florida St., where Longfellow Creek is currently located, was part of Elliott Bay and was used for floating log storage. This area was filled sometime after 1974. Because of these changes in the shoreline, contamination found offshore of this area is probably associated with relatively recent activities (i.e., within the last 20 yr).

North Harbor Island II problem area ranked as a high-priority area based primarily on sediment chemistry. Contamination in the offshore sediments was predominated by PAH, with less widespread contamination by PCBs (see Table 5-2) (PTI and Tetra Tech 1988). The most severe contamination in the problem area was localized, suggesting local contaminant sources. The highest PAH concentrations occurred near Stations NH-06 and NH-08. Station NH-06 was located just north of the pier at the Wyckoff property, and Station NH-08 was located approximately 250 ft offshore of the mouth of Longfellow Creek (see Figure 4-10). Although the metal concentrations in the problem area did not exceed HAET, at least one metal exceeded the LAET at most offshore stations (Table PTI-40 in PTI and Tetra Tech 1988). Metals that exceeded LAET in the offshore sediments included cadmium (0.17-7.3 mg/kg) mercury (0.016-0.675 mg/kg), and zinc (110-691 mg/kg).

LPAH concentrations exceeded the HAET (6,100 ug/kg) at seven stations in the North Harbor Island II problem area (see Table 5-2) (PTI and Tetra Tech 1988). The highest concentrations of LPAH in the problem area occurred at Stations NH-06 (57,000 ug/kg), NH-08 (37,000 ug/kg) and historical Stations E44 (85,600 ug/kg; U.S. EPA 1983) and E43 (83,600 ug/kg; U.S. EPA 1983). Historical Station 8 (Gamponia et al. 1986), which was located shoreward of Stations NH-08 and E44 (see Figure 4-10), did not have high concentrations of LPAH (4,730 ug/kg). An intertidal station (NH-07) located between Stations NH-06 and NH-08 also contained substantially lower concentrations of LPAH (9,230 ug/kg). Although the sediment at Station NH-07 was more coarse-grained (10 percent fines) than the sediments at Stations NH-06 and NH-08 (approximately 53 percent fines), the LPAH concentration normalized for percent fines exhibited substantially lower concentrations of LPAH at Station NH-07. This difference suggests that the LPAH contamination at Stations NH-06 and NH-08 originated from sources close to each station.

HPAH concentrations exceeded the HAET (38,000 ug/kg) at six stations in the problem area (see Table 5-2) (PTI and Tetra Tech 1988). Stations NH-06 and NH-08 were highly contaminated with PAH compounds. The HPAH concentrations (130,000 and 79,000 ug/kg, respectively) measured at these

stations were among the highest concentrations observed in the study. The highest concentrations of HPAH at historical stations in the North Harbor Island II problem area occurred at Stations E44 (85,200 ug/kg; U.S. EPA 1983) and E43 (159,500 ug/kg; U.S. EPA 1983). Station NH-07, located between Stations NH-06 and NH-08, was an intertidal station with coarser-grained sediments and a much lower concentration of HPAH (E650 ug/kg) than either NH-06 or NH-08. The nearshore historical Station 7 (Gamponia et al. 1986) also contained lower concentrations of HPAH (9,558 ug/kg) than other nearby offshore sediment stations.

PCB concentrations (ranging from 99 to 6,600 ug/kg) in the North Harbor Island II problem area exceeded the HAET (2,500 ug/kg) at historical Stations S0034 (2,800 ug/kg; Romberg et al. 1984) and 7 (6,600 ug/kg; Gamponia et al. 1986). In addition, although the HAET for PCBs was not exceeded, PCB concentrations at two Elliott Bay study stations in the area (NH-06 and NH-08) had EAR values greater than or equal to 100. PCB concentrations were not apparent in the offshore sediments. It was apparent that PCB contamination did not covary with PAH contamination (PTI and Tetra Tech 1988); therefore, PCB contamination in the offshore sediments was probably caused by different sources than the PAH contamination.

Potential Contaminant Sources--

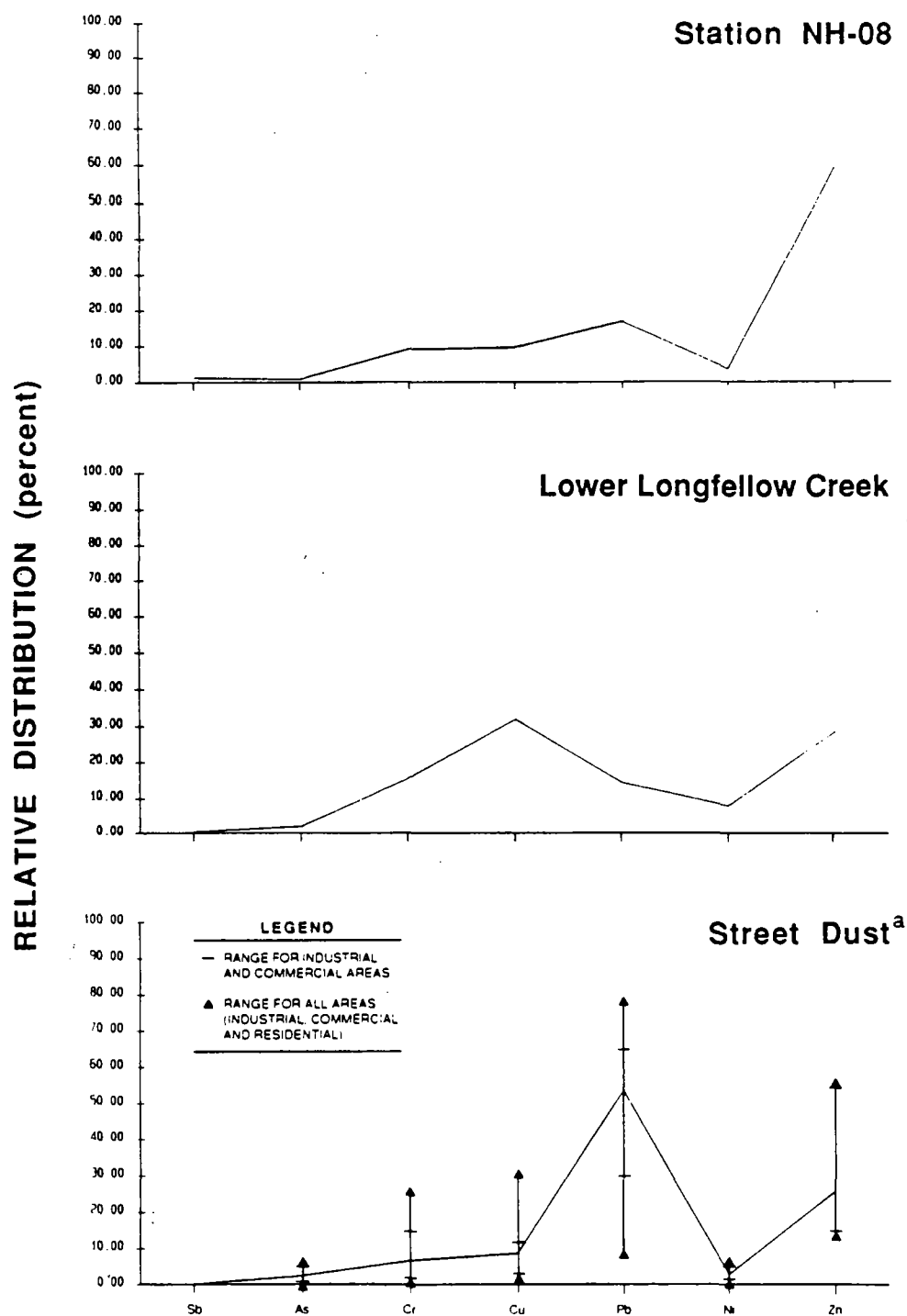
Lower Longfellow Creek--Lower Longfellow Creek is the only drain that was sampled in the North Harbor Island II problem area during the Elliott Bay Action Program sampling effort. The sediment sample from Longfellow Creek was collected from the bank of a pond on the lower portion of Longfellow Creek (about 500 ft south of SW Florida St.), where the influent pipe enters the upstream side of the pond. The pond receives runoff from the area west of the pond (currently occupied by a scrap yard), as well as flow from the upper basin and NPDES-permitted discharges from Seattle Steel.

Lower Longfellow Creek discharges into Elliott Bay near Station NH-08 and historical Stations E44 (U.S. EPA 1982, 1983) and 8 (Gamponia et al. 1986) (see Figure 4-10). The concentration of copper, 4-methylphenol, p,p'-DDT, and PCBs in the sediment sample from lower Longfellow Creek

exceeded HAET. The concentration of nickel (309 mg/kg) exceeded the 90th percentile concentration (223 mg/kg). The lower Longfellow Creek serves approximately 120 ac in West Seattle and flows through a series of ditches, pipes, and ponds prior to discharging into Elliott Bay. The creek currently receives NPDES-permitted discharges from Seattle Steel (see Table 2-4).

Historically, the entire Longfellow Creek basin (1,500 ac) discharged into Elliott Bay in the North Harbor Island II problem area. Three city CSOs (168, 169, and 170) discharged into the upper Longfellow Creek basin, but these three CSOs were eliminated with the implementation of the 1980 CSO control plan (Corson, C., 6 May 1988, personal communication). Currently, only flow from the lower Longfellow Creek basin (120 ac) discharges into the problem area. Flow from the upper basin (1,400 ac) is diverted at SW Andover Street to the West Waterway via the SW Hinds CSO/SD (099) (see Map 3 in Map Appendix). However, during periods of high flow, discharges from the upper basin may overtop the diversion structure and some flow from the upper basin would discharge to Elliott Bay in North Harbor Island II problem area via lower Longfellow Creek.

With the exception of PCBs, the problem chemicals identified in the sediment from lower Longfellow Creek (i.e., copper, nickel, 4-methylphenol, p,p'-DDT, and PCBs) do not match the problem chemicals identified in the nearby offshore sediment samples (i.e., LPAH, HPAH, and PCBs). A comparison of the relative distribution of metals in sediments from lower Longfellow Creek and offshore sediments is shown in Figure 5-7. Zinc was the predominant metal found in the offshore sediments, constituting 60 percent of the total metals evaluated (sum of antimony, arsenic, chromium, copper, lead, nickel, and zinc). The lower Longfellow Creek sediments contained a higher percentage of copper (31 percent) and a lower percentage of zinc (30 percent) than the offshore sediments. Although the available data indicate that lower Longfellow Creek is a source of metals, particularly copper, nickel, and PCBs into the problem area, metals were not identified as problem chemicals in the offshore sediments. Because of differences in the chemical composition of drain and offshore sediments, a link between the drain and receiving environment could not be demonstrated at the time of sample collection.



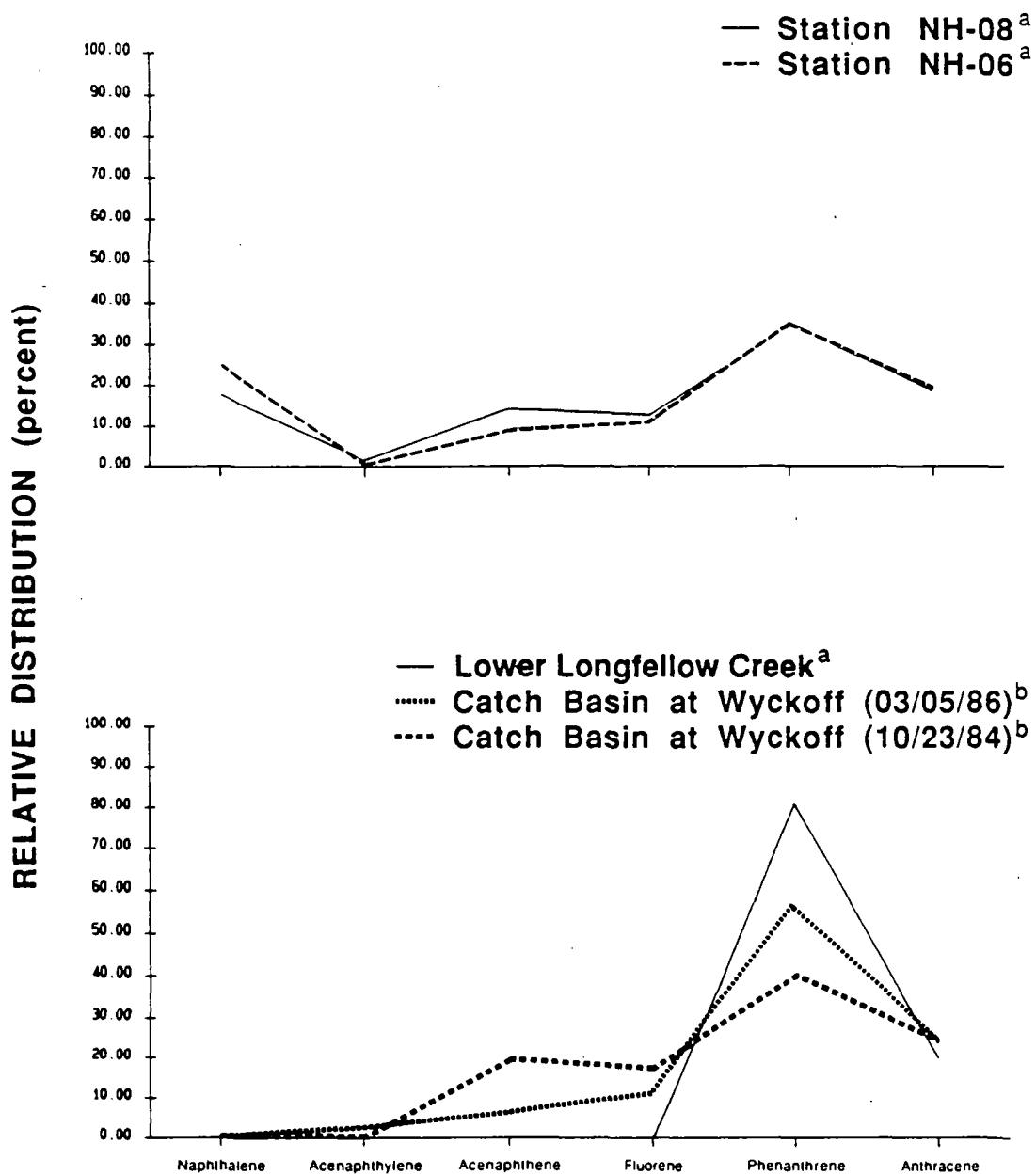
^a Reference: Galvin and Moore (1982).

Figure 5-7. Comparison of relative percent distribution of metals in offshore sediment from North Harbor Island II problem area and a nearby drain.

The relative distribution of PAH compounds in the lower Longfellow Creek sediment sample also did not match offshore sediments. Offshore sediments contained a combination of LPAH compounds (17 percent naphthalene, 13 percent acenaphthene, 11 percent fluorene, 35 percent phenanthrene, and 20 percent anthracene), but the lower Longfellow Creek sample contained only phenanthrene (80 percent) and anthracene (20 percent) (Figure 5-8). LPAH concentrations in the nearby offshore sediments (37,300-85,600 ug/kg) were about 3 orders of magnitude greater than the concentrations observed in lower Longfellow Creek (E730 ug/kg).

In 1987, Ecology responded to a spill complaint in the upper Longfellow Creek basin (Ecology 1987). The inspection report tentatively identified the spill as gasoline or solvent, which left a visible sheen on Longfellow Creek. Although this 1987 spill would not have affected the samples discussed in this report, the inspection report noted that there have been historical contamination problems in the Longfellow Creek basin (Ecology 1987). It is likely that past spills in the Longfellow Creek basin have contributed to the PAH contamination observed in offshore sediments. It is not known how effective the ponds on the lower end of Longfellow Creek are in trapping contaminants discharged from the basin. Because the concentrations of LPAH observed in the sediments offshore of lower Longfellow Creek (37,000-85,600 ug/kg) were substantially higher than the concentration measured in the lower Longfellow Creek sample (E730 ug/kg), there may have been other sources of LPAH in this area.

The most abundant HPAH compounds found in the offshore sediments (Figure 5-9) were pyrene (23 percent) and benzofluoranthenes (26 percent). Fluoranthene (30 percent), pyrene (23 percent), chrysene (23 percent), and benzofluoranthenes (20 percent) were the most abundant HPAH compounds in the sediment from lower Longfellow Creek. The concentration of PAH in the lower Longfellow Creek sample (E6,490 ug/kg) was substantially lower than the concentration in the offshore sediment samples (39,000-79,000 ug/kg). Sources other than lower Longfellow Creek may have contributed to the PAH contamination found in the offshore sediments.



a This study.

b Sample, T., 23 October 1987, personal communication.

Figure 5-8. Comparison of relative percent distribution of LPAH in offshore sediment from North Harbor Island I problem area and a nearby drain.

The concentration of PCBs exceeded the LAET (130 ug/kg) at two stations offshore of lower Longfellow Creek (Station NH-08=E1,300 ug/kg; Station 8=L490 ug/kg, Gamponia et al. 1986). PCB was identified as a problem chemical in the lower Longfellow Creek sediment sample (E6,100 ug/kg), indicating that lower Longfellow Creek was a potential source of the PCB contamination in this area.

Wyckoff Company--Most of the shoreline adjacent to the North Harbor Island II problem area is occupied by the Wyckoff Company's wood treatment facility. Wyckoff has operated at its current location since approximately 1906 (Woodward-Clyde Consultants 1985). Wyckoff Company treats wooden poles, railroad ties, and posts with preservatives (i.e., creosote, pentachlorophenol, and copper-arsenate salts) (Black & Veatch 1985). Ecology identified the raw materials used at the facility as arsenic acid, ammonia, pentachlorophenol, creosote, and Bunker C fuel oil (Ecology 1987). In addition, Wyckoff stores the following waste sludges onsite: pentachlorophenol sludge, copper arsenate sludge, and creosote sludge (Sweet-Edwards & Associates and Harper-Owes 1985).

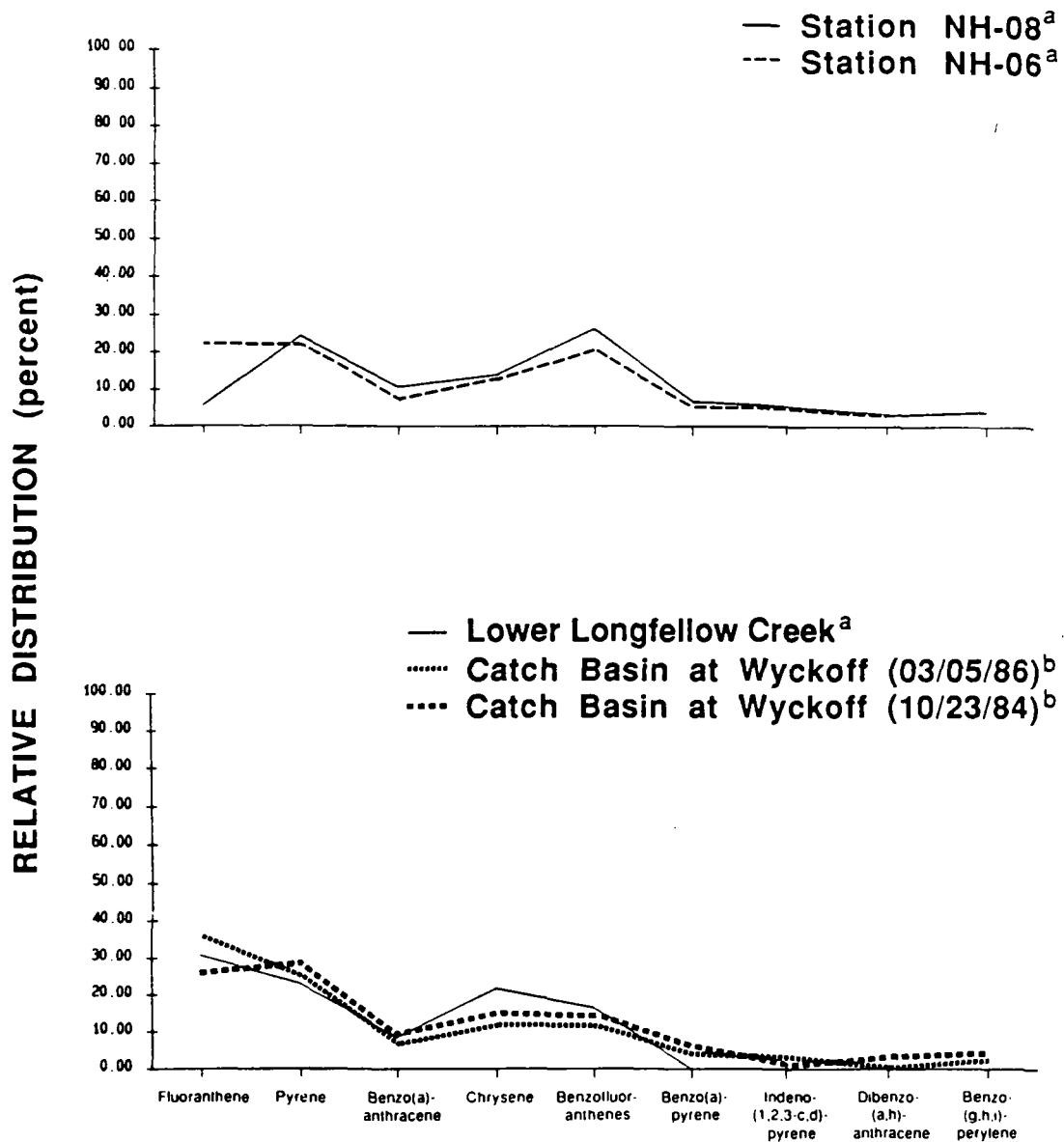
Wyckoff Company is currently under a Consent Order to investigate and remediate contamination problems at their property (Pierce, W., 8 December 1987, personal communication). Results of investigations conducted by U.S. EPA and Metro in 1983 and 1984 determined that Wyckoff had illegally discharged wastewater from their facility into a catch basin. The catch basin is connected to the SW Florida CSO/SD (098), which discharges into the West Waterway. U.S. EPA also found that Wyckoff had illegally disposed of hazardous wastes in an unlined pond onsite (McClary, D., 6 November 1987, personal communication). Metro found that the catch basin sediments were contaminated with HPAH, LPAH, pentachlorophenol, arsenic, and copper (Hubbard and Sample 1988). Soil samples collected from the Wyckoff site contained 25-30 percent creosote (McClary, D., 6 November 1987, personal communication). PAH compounds are a major component of creosote mixtures.

The relative distribution of LPAH in sediments from Stations NH-06 and NH-08, and the Wyckoff catch basin are shown in Figure 5-8. The data for the catch basin sediments (Sample, T., 23 October 1987, personal communication)

are used as an example of the contaminants associated with the Wyckoff property. The relative distribution of individual LPAH compounds in Stations NH-06 and NH-08 was similar. Phenanthrene was the most abundant LPAH compound (35 percent in both samples), followed by naphthalene (26 and 18 percent, respectively), and anthracene (18 and 19 percent, respectively). With the exception of naphthalene, the relative distribution of LPAH in the sediments collected by Metro (Sample, T., 23 October 1987, personal communication) from the catch basin on Wyckoff property in 1984 was similar to that of the offshore stations.

Metro's 1984 catch basin samples were collected before the SW Florida CSO/SD (098) was cleaned by the City of Seattle (see Section 4.3.6). Contaminated sediments were removed from the SW Florida CSO/SD (098) in July and August 1984. Metro's 1986 catch basin sample (Sample, T., 27 March 1987, personal communication) contained a higher relative abundance of phenanthrene (56 percent) than the 1984 sample and the offshore sediments. The 1986 catch basin samples were collected after the drain and catch basin were cleaned. The illegal discharge of materials from Wyckoff Company had also ceased by this time. The Wyckoff property was potentially the major source of LPAH contamination at Station NH-06, because of its proximity to Station NH-06 and similarities of contaminants found in both places. However, it is not known if discharges from the Wyckoff property were responsible for the contamination at Station NH-08. Although the relative distribution of LPAH compounds in the offshore sediments at Station NH-08 and Wyckoff catch basin sediments matched relatively well, the low LPAH concentrations observed at intertidal Station NH-07, located between Stations NH-06 and NH-08, suggests that there may have been a local source of LPAH near Station NH-08. Further investigation is required to determine if the Wyckoff facility contributed to the LPAH contamination at Station NH-08.

The relative distribution of HPAH compounds in offshore sediment from Stations NH-06 and NH-08, and the potential sources of HPAH (i.e., lower Longfellow Creek and Wyckoff catch basin) are shown in Figure 5-9. With the exception of fluoranthene, these relative distributions were similar in the two offshore sediment stations. Station NH-06 contained a greater relative abundance of fluoranthene (21 percent) than Station NH-08 (6 percent). The



a This study.

b Sample, T., 23 October 1987, personal communication.

Figure 5-9. Comparison of relative percent distribution of HPAH in offshore sediment from North Harbor Island II problem area and a nearby drain.

similarities in HPAH relative distributions indicate that the contamination at these two stations could have been from the same or similar sources. The relative distributions of HPAH in the catch basin and lower Longfellow Creek sediment samples were similar to those for the offshore sediments, indicating that lower Longfellow Creek and the Wyckoff facility were probably contributing to the HPAH contamination offshore. Because the concentrations measured in the catch basins on Wyckoff property were 2 orders of magnitude greater than the concentrations measured in lower Longfellow Creek, it appears that the Wyckoff facility was the larger source of PAH to problem area North Harbor Island II. However, further investigation is required to determine the relative contaminant contributions from each of these two sources.

Station NH-06 was located offshore of Wyckoff Company's creosote storage tanks. Ecology reported in 1986 that the tanks at the facility were bermed, but not sealed. At that time, the tank area remained unsealed at the request of the Seattle Fire Department to reduce the fire hazard from any material spilled or leaked from the tanks (Ecology 1987). During high tide, the water table is less than 1 ft below ground surface in this area. Because of the high water table, contaminants spilled on the ground could readily contaminate the groundwater beneath the site and be transported into Elliott Bay. In addition, Ecology reported that the tank farm floods when 13-ft tides and low barometric pressure occur simultaneously. Flooding of the tank farm area provides a direct pathway of contaminants from the area into Elliott Bay.

No specific sources of PCBs have been documented at the Wyckoff facility. The highest concentrations of PCBs observed in the offshore sediments occurred at historical Station 8 (6,600 ug/kg; Gamponia et al. 1986), which was located offshore of Longfellow Creek.

West Seattle Landfill--The West Seattle landfill is a potential source of contaminants to problem area North Harbor Island II through groundwater transport. The West Seattle landfill was operated by the City of Seattle between 1939 and 1966. The 20-ac landfill was located on the west side of the West Waterway south of SW Florida St. between SW Harbor Ave. and the

railroad tracks (see Figure 5-1). The landfill is no longer active, and most of the area has been developed for industrial use.

Although the landfill accepted primarily municipal wastes, because of its location in an industrial area, the landfill is also suspected to contain industrial wastes (Tetra Tech 1986b). The Seattle-King County Department of Public Health reported that steel-mill wastes and fertilizer-plant wastes were deposited in the landfill (Seattle-King County Department of Public Health 1984). It is reported that hog fuel and sawdust were used as a cover material for the landfill in the 1940s (Sweet-Edwards and Associates and Harper-Owes 1985). The site has had problems with underground fires (Tetra Tech 1986b). For approximately 3 mo in 1965, the Seattle Fire Department used a 500 ft² area of the landfill for their oil fire control school (Seattle-King County Department of Public Health 1984).

Data collected by Metro as part of the Renton Effluent Transfer Project indicated that soil and groundwater in the vicinity of the landfill were contaminated with PAH and other extractable organic compounds (Converse Consultants 1985). Soil corings and groundwater samples were collected during excavation for the transfer pipeline. Samples were collected from stations along Harbor Ave. SW, which is located on the west side of the old landfill area. These soils contained as much as 0.40 percent PAH. Water samples contained as much as 123,000 ug/L total extractable organic compounds. Contaminated groundwater from underneath the landfill may discharge into Elliott Bay and contribute to the contaminants observed in the problem area.

Summary--

Contamination in the North Harbor Island II problem area was predominated by PAH, with less widespread contamination by PCBs. The distribution of PAH in the offshore sediments suggest that there may have been localized contaminant sources in the problem area. The Wyckoff facility was identified as the potential source of PAH in the immediate area offshore of the north end of the property adjacent to Station WW-08 (see Figure 4-10). The extent of the contamination from the facility could not be determined. The PAH

contamination observed at Station NH-06 appears to be related to discharges from lower Longfellow Creek, primarily because lower Longfellow Creek discharges into Elliott Bay in the immediate vicinity of this station. Lower Longfellow Creek was identified as a potential source of PCBs in the North Harbor Island II problem area. However, because of the patchy distribution of PCBs in the offshore sediments, it appears that there were multiple sources of PCBs in the problem area.

5.1.4 West Waterway I Problem Area

The southern half of West Waterway (see Figure 5-1) was designated a high-priority problem area because of biological effects (PTI and Tetra Tech 1988). Although only moderate chemical contamination was observed in the offshore sediments, many stations exhibited severe biological effects. Some localized areas of contamination by organic compounds (particularly PAH and PCBs) were observed in the problem area. Concentrations of a few metals exceeded the LAETs at offshore stations located in the southwest corner of the waterway. Problem chemicals identified at each station are summarized in Table 5-3.

None of the offshore stations in the West Waterway 1 problem area had metal concentrations exceeding the HAETs. However, both lead and mercury concentrations exceeded the LAETs (300 mg/kg and 0.41 mg/kg, respectively) at Stations WW-06 and S0036, and mercury also exceeded the LAET at Station 14 (Gamponia et al. 1986). All these stations were located in the southwest corner of the waterway, in the vicinity of the SW Hinds CSO/SD (see Figure 4-17). The zinc concentration (E344 mg/kg) at Station WW-06 also exceeded the LAET (260 mg/kg). An isolated occurrence of zinc contamination was identified at Station WW-02 (E266 mg/kg) located at the southern end of the problem area.

PAHs and PCBs were the most common extractable organic contaminants identified in the West Waterway I problem area. Severe PAH contamination was observed at Station WW-04, which was located adjacent to the 16th Ave. SW CSO/SD (104) (see Figure 4-17). Concentrations of both LPAH (E15,170 ug/kg) and HPAH (E52,520 ug/kg) exceeded the HAETs for these

TABLE 5-3. HAET AND LAET EXCEEDANCES IN THE WEST WATERWAY PROBLEM AREAS^a

Area	Station	HAET Exceedances ^b									LAET Exceedances ^c
		LPAH	HPAH	PCBs	CU	PB	p,p'- DDT/DDD	2,4MEPHNL	BNZO	DMP	
West Waterway I	WW-01										PCBs
	WW-02								X		PCBs, ZN
	WW-03										
	WW-05										PCBs
	WW-04	X	X								PCBs
	WW-06	X								X	PCBs, PB, HG, ZN, BUTBNZPH, HPAH
	GAMP14 ^d			X							HPAH, HG
	S0036 ^e	X	X				X				PCBs, PB, HG
	WW-08								X		PCBs, HG, BUTBNZPH [4MEPHNL]
	GAMP12 ^d							X			HPAH, LPAH, PCBs
West Waterway II	WW-11					X					HPAH, LPAH, HG, PCBs, ZN [TOTXYLENE]
	WW-09		X	X			X	X			CU, HG, PCBs, ZN
	WW-12	X	X			X					AS, CU, HG, ZN, PCBs [CR]
	WW-10										HPAH, PB, HG, ZN, PCBs
	WW-13									X	LPAH, HPAH, HG
	GAMP9 ^d	X		X	X	X		X			HPAH, AS, HG, ZN
	GAMP10 ^d			X							HPAH, LPAH, HG, ZN
	GAMP11 ^d	X									HPAH, PCBs, HG
	WW-14		X			X					PCBs, LPAH, HG, ZN [CD]
	WW-18		X								PB, HG, ZN, PCBs, DDD
	WW-16										LPAH, HPAH, PCBs, HG, ZN
	WW-15										[PHNL]
	WW-17		X								LPAH, PCBs, DMP, HG, ZN

^a LPAH - Signifies AET exceedances for the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene, or any of these compounds individually. To simplify the presentation of AET exceedances in this table, exceedances of AET for 1-methylphenanthrene, 2-methylnaphthalene, biphenyl, and dibenzofuran are included under LPAH. These compounds covaried with LPAH but are not included in LPAH sums.

HPAH - Signifies AET exceedances for the sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene, or of any of these compounds individually.

CU - copper

PB - lead

ZN - zinc

HG - mercury

CD - cadmium

AG - silver

AS - arsenic

PHNL - phenol

4MEPHNL - 4-methylphenol

2MEPHNL - 2-methylphenol

2,4MEPHNL - 2,4-dimethylphenol

BNZO - benzyl alcohol

BNZACID - benzoic acid

1,4DICLBZ - 1,4-dichlorobenzene

BUTBNZPH - butyl benzyl phthalate

DMP - dimethyl phthalate

TOC - total organic carbon

DINOCT - di-n-octyl phthalate

TOTXYLENE - total xylenes

CR - chromium

ENDALD - endrin aldehyde

PCP - pentachlorophenol

^b Chemicals exceeding HAET for Puget Sound.

^c Chemicals exceeding LAET for Puget Sound. Chemicals shown in brackets exceeded 90th-percentile concentrations but did not exceed any AET. Chemicals exceeding both AET and 90th-percentile concentrations are not bracketed.

^d Gamponia et al. (1986).

^e Romberg et al. (1984).

Reference: PTI and Tetra Tech (1988).

compounds (6,100 and 38,000 ug/kg, respectively). Concentrations at nearby Stations WW-03 and WW-05 were more than 1 order of magnitude lower despite comparable grain size and TOC content (PTI and Tetra Tech 1988). PAH concentrations exceeding the HAET were also observed at Station WW-06 (HPAH=E10,230, LPAH=E7,310) and nearby historical Station S0036 (see Table 5-3) located in the southwest corner of the West Waterway.

PCB contamination was widespread in this problem area. Six of the seven stations sampled during the Elliott Bay Action Program had PCB concentrations exceeding the LAET (130 ug/kg) (see Table 5-3). The single station showing no elevation of PCB concentration (WW-03) was located in the navigation channel (see Figure 4-17) and had been dredged as recently as 1970 (see Figure G-5 in Appendix G). PCB concentrations described by Gamponia et al. (1986) indicated even higher levels of contamination in this problem area. Station 14 (Gamponia et al. 1986), located in the southwest corner of the waterway, had the highest PCB concentration (24,000 ug/kg) found at any station (PTI and Tetra Tech 1988). However, sediments from Station WW-06, located nearby contained PCBs at a concentration approximately 40 times lower (PTI and Tetra Tech 1988).

Single HAET exceedances for dimethyl phthalate (HAET=160 ug/kg) and 2,4-dimethylphenol (HAET=63 ug/kg) were observed at Stations WW-06 and Station 12 (Gamponia et al. 1986), respectively. The highest concentration of benzyl alcohol in the present study (E8,800 ug/kg) was observed at Station WW-02 at the south end of the waterway (see Figure 4-17). Sediments from Station WW-08 at the opposite end of the waterway also contained benzyl alcohol at a concentration exceeding the HAET (140 ug/kg). However, relatively high detection limits prevented interpretation of this compound's spatial distribution. One historical station (S0036) slightly exceeded the HAETs for p,p'-DDT and p,p'-DDD (Romberg et al. 1984). The p,p'-DDT concentration at this station was 54 ug/kg (HAET=43 ug/kg) and the p,p'-DDD concentration was 12 ug/kg (HAET=11 ug/kg).

Potential Contaminant Sources--

Sediment samples were collected from three CSOs in the West Waterway I problem area: SW Hinds CSO/SD (099), SW Spokane CSO/SD (102), and 16th Ave. SW CSO/SD (104) (see Figure 4-17). The Chelan CSO was not sampled because of insufficient sediment deposits in the drain. The potential contribution from each of these CSO/SDs to chemical contamination in the offshore sediments is discussed below.

SW Hinds CSO/SD (099)--The problem chemicals identified in the SW Hinds CSO/SD were not the same as those identified in nearby offshore sediments (see Tables 4-1 and 5-3). 4-Methylphenol (E19,000 ug/kg) was the only problem chemical observed in the SW Hinds CSO/SD sediments (see Table 4-1). Although 4-methylphenol did not exceed the LAET in the offshore sediments nearby, it did exceed the 90th percentile concentration at Station WW-08 (E360 ug/kg), downstream of the SW Hinds CSO/SD. Sediments from Station WW-06, the offshore station closest to the SW Hinds CSO/SD discharge, exceeded the HAET for LPAH and dimethyl phthalate, and the LAET for PCBs, lead, mercury, zinc, butyl benzyl phthalate, and HPAH (PTI and Tetra Tech 1988). Relatively low concentrations of these chemicals in the SW Hinds CSO/SD indicate that the CSO/SD may not have been a substantial ongoing source of these pollutants in the nearby offshore sediments at least during the sample collection period.

SW Spokane CSO/SD (102)--Nickel (263 mg/kg) and chromium (E2,270 mg/kg) were identified as problem chemicals in the SW Spokane CSO/SD (see Table 4-1). The chromium concentration (E2,270 mg/kg) was the highest observed among all the CSO/SDs in the project area. Possible sources of these chemicals in the drainage basin are discussed in Section 4.3 of this report. The offshore stations closest to this drain (WW-01 and WW-02) were located approximately 320 ft downstream of the drain outfall. Neither nickel nor chromium were substantially elevated at these offshore sediment stations (Station WW-01: nickel=25.5 mg/kg, chromium=35 mg/kg; Station WW-02: nickel=41.1 mg/kg, chromium=E105 mg/kg). The relative distribution of metals in the sediments from the SW Spokane CSO/SD (102) and offshore Station WW-01 are presented in Figure 5-10. The relative abundance

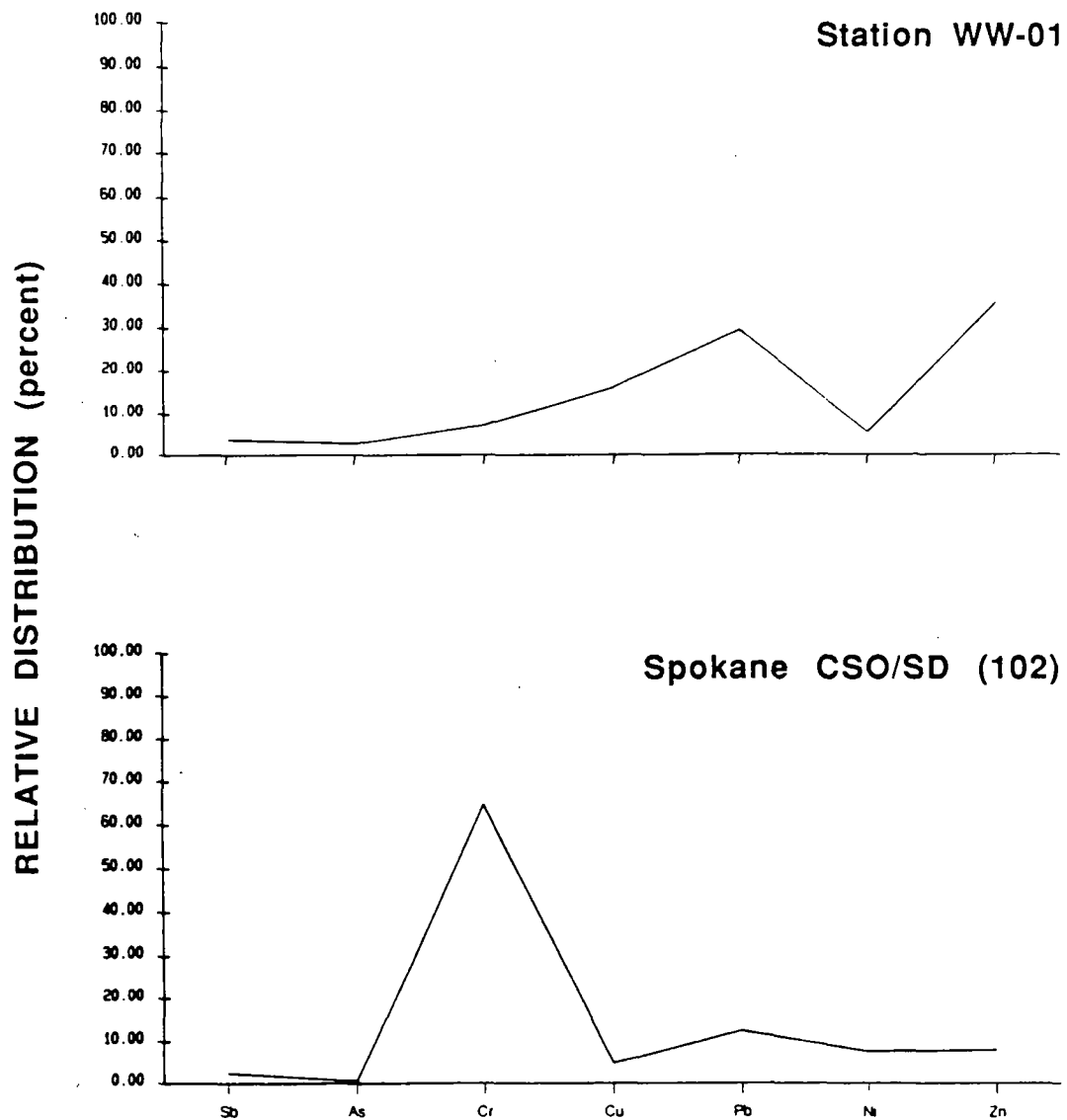


Figure 5-10. Comparison of relative percent distribution of HPAH in offshore sediment from West Waterway I problem area and a nearby drain.

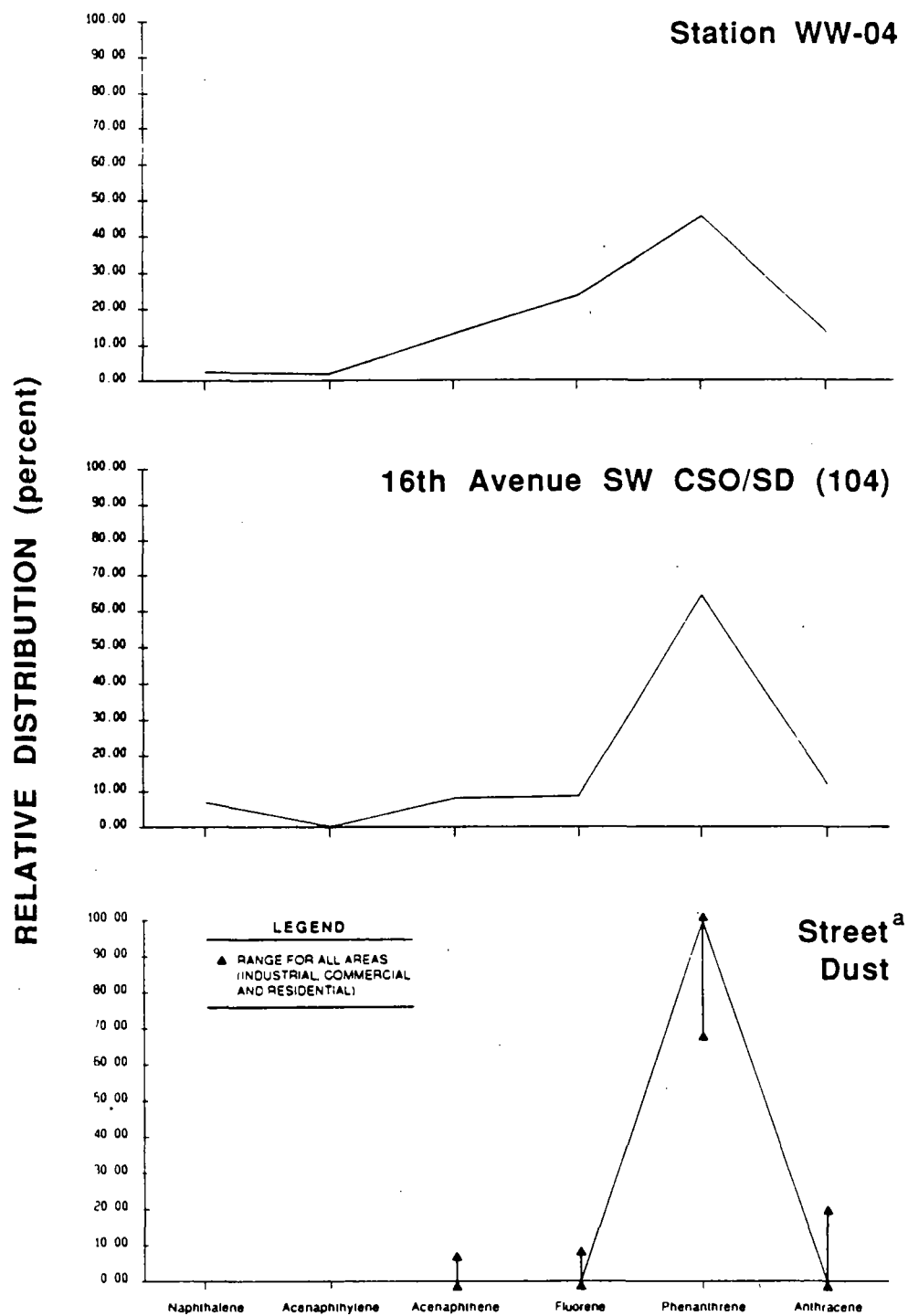
of chromium (65 percent) in the CSO/SD sediment was much greater than in the sediment from Station WW-01 (8 percent). Zinc was the only metal that exceeded the LAET at either of the offshore stations (E266 mg/kg at Station WW-02). Zinc also exceeded the LAET (260 mg/kg) in the CSO/SD sediment (E275 mg/kg), indicating that the drain may have contributed zinc to the offshore sediments.

The PCB concentration (E510 ug/kg) exceeded the LAET (130 ug/kg) at Station WW-02 and also exceeded the LAET in the CSO/SD sediment (434 ug/kg), indicating that the drain could have been contributing this chemical to offshore sediments. Benzyl alcohol exceeded the HAET at Station WW-02 (E8,800 ug/kg), but the high detection limit (7,000 ug/kg) for benzyl alcohol in the drain sediment sample precludes drawing conclusions concerning the drain as a source of this contamination.

The above observations indicate that the SW Spokane CSO/SD may have been contributing zinc and PCBs to the offshore sediments. However, during sediment sampling of the Spokane CSO/SD, it was observed that the manhole appeared to contain a substantial amount of material that was similar to fill dirt recently deposited near the site. Therefore, the data on the sediment from the drain may represent the chemical contamination in fill dirt deposited in the CSO/SD, and not yet deposited offshore.

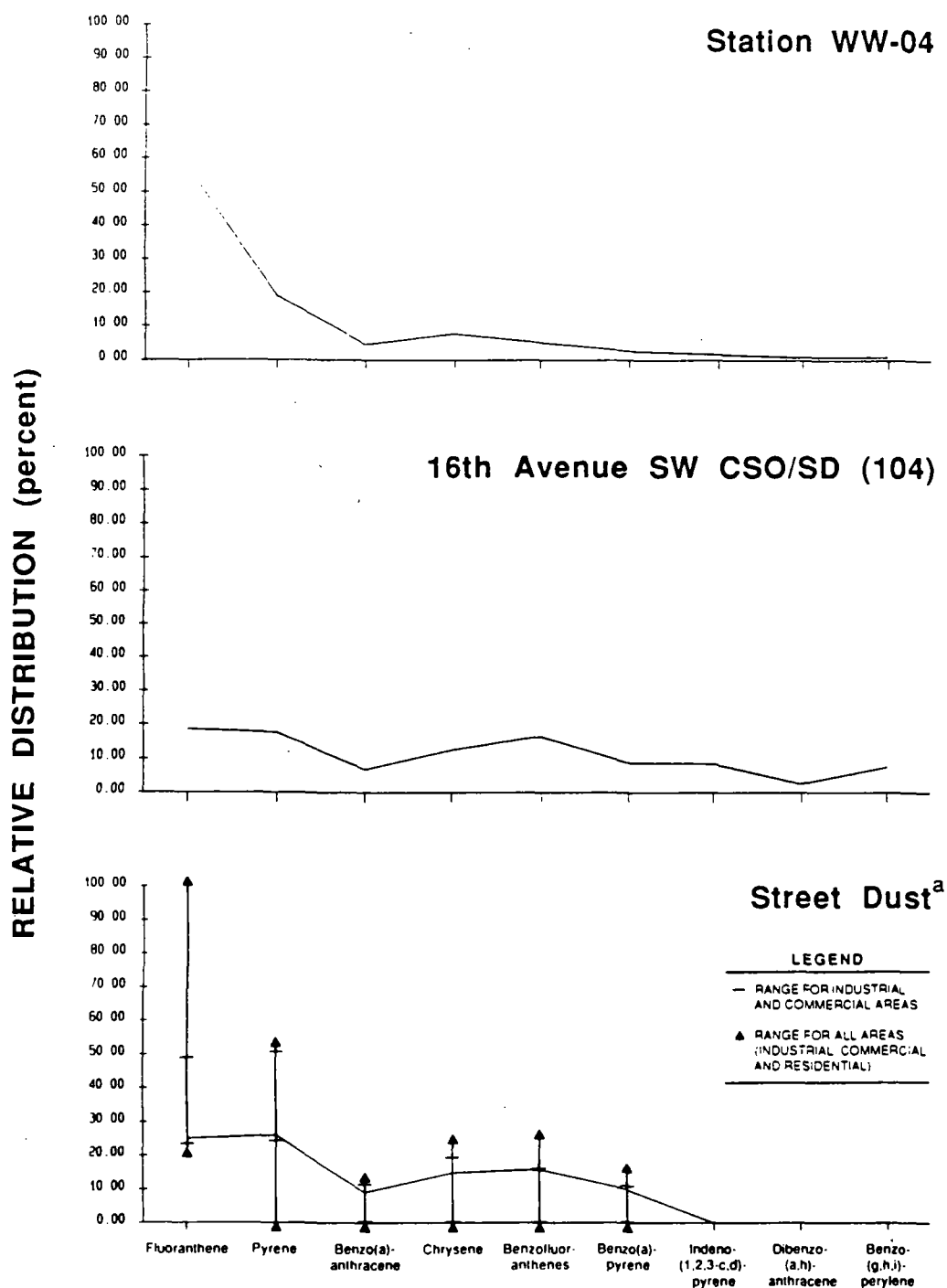
16th Ave. SW CSO/SD (104)--Four problem chemicals were identified in the 16th Ave. SW CSO/SD: 1-methylphenanthrene (E470 ug/kg), lead (901 mg/kg), 2-methylphenol (E3900 ug/kg), and p,p'-DDT (E21 ug/kg) (see Table 4-1). Both HPAH and LPAH concentrations (E52,520 and E15,170 ug/kg, respectively) exceeded the HAETs in sediments from Station WW-04 offshore of the CSO outfall. 1-methylphenanthrene (E480 ug/kg) also exceeded the HAET at Station WW-04.

The relative distributions of the PAH compounds in street dust and in sediments from the 16th Ave. SW CSO/SD and offshore Station WW-04 are compared in Figures 5-11 and 5-12. The relative distributions of LPAH compounds in the sediments from the 16th Ave. SW CSO/SD and Station WW-04 were similar to the distribution of LPAH in street dust samples. However,



^a Reference: Galvin and Moore (1982).

Figure 5-11. Comparison of relative percent distribution of LPAH in offshore sediment from West Waterway I problem area and a nearby drain.



^a Reference: Galvin and Moore (1982).

Figure 5-12. Comparison of relative percent distribution of HPAH in offshore sediment from West Waterway I problem area and a nearby drain.

the concentration of LPAH in the offshore sediment (E15,170 ug/kg) was as much as 1 order of magnitude greater than the concentrations measured in the CSO/SD (E1,860 ug/kg) and street dust samples (300-3,400 ug/kg; Galvin and Moore 1982). This difference suggests that there may have been additional sources besides the CSO/SD contributing to the LPAH contamination in the offshore sediments.

The relative distribution of HPAH compounds in the offshore sediment and the CSO/SD was not similar. The offshore sediment contained a greater abundance of fluoranthene (58 percent) than the CSO/SD (20 percent), but the relative distribution of HPAH in both the CSO/SD and the offshore sediment was within the ranges measured in street dust. However, as in the case of LPAH, the HPAH concentration measured in the offshore sediment (52,520 ug/kg) was as much as 1 order of magnitude greater than the concentration in the CSO/SD (E10,220 ug/kg) and the street dust samples (800-9,500 ug/kg; Galvin and Moore 1982). This difference suggests that there may have been additional sources contributing to the HPAH contamination observed in the offshore sediments.

Lead was identified as a problem chemical in the 16th Ave. SW CSO/SD sediments but not in the offshore sediments at Station WW-04. The concentration of lead in the drain (901 mg/kg) was within the range of lead concentrations measured in street dust (380-1,100 mg/kg) collected from commercial and industrial areas. Therefore, at the time of sample collection, the CSO/SD sediment may not have contributed substantially more lead to the offshore sediments than expected from typical surface runoff. Neither 2-methylphenol nor p,p'-DDT contamination was observed in the offshore sediments, although both were problem chemicals in the drain. The above observations indicate that the 16th Ave. SW CSO/SD may have been the primary source of the problem chemicals observed in the offshore sediments.

Chelan CSO (W036)--The Chelan CSO was also a potential source of contamination to the West Waterway offshore sediments. This CSO was not sampled during the present study because of insufficient sediment deposits. Seattle Steel and Wyckoff Company are the only facilities in the Chelan CSO basin with Metro industrial pretreatment permits. Both discharges are

monitored for cadmium, chromium, copper, nickel, lead, and zinc. Surface runoff from these and other facilities in the basin is to Longfellow Creek or private storm drain systems. Further investigation is required to determine if the Chelan CSO is a source of contamination in the offshore sediments.

Other Potential Sources--The CSO/SD discharges, while contributing some contamination to the offshore environment, do not appear to account for most of the problem chemicals observed in the offshore sediments at least during the time of sample collection. The general elevation of PAH and PCB concentrations and the isolated occurrences of metal, 2,4-dimethyl phenol, benzyl alcohol, and dimethyl phthalate contamination may derive from historical or ongoing nonpoint sources. In addition, the widespread PCB and PAH contamination suggests multiple sources of these compounds.

Potential nonpoint sources of chemical contamination in the offshore sediments include 1) industrial facilities located adjacent to the waterway 2) industries that, although not bordering the waterway, are potential contributors to contamination through groundwater seepage, and 3) accidental spills. Waterfront industries have the greatest potential for directly affecting the offshore environment. However, in the West Waterway I problem area, the industries adjacent to the waterway generally do not appear to be associated with the chemical contaminants observed in the offshore sediments.

Fisher Mills, Inc. is the major property owner on the entire east side of the West Waterway I problem area. The main facility is located on the north end of the problem area, but Fisher also owns a narrow strip of property extending south along the waterfront. The property is served by a private storm drain system. Fisher Mills discontinued their discharge of boiler blow down water to the West Waterway in August 1986 when it was rerouted to the sanitary sewer. The facility currently has a NPDES permit to discharge noncontact cooling water via two outfalls (Cargill, D., 19 August 1988, personal communication). Columbia Northwest Corporation operates a cement distribution facility, located adjacent to the east side of the waterway near Spokane St. SW. No manufacturing is conducted at the site, and no known problem chemicals are present.

On the west side of the waterway, Terminal 5, operated by the Port of Seattle, is the major land user. Various smaller, privately owned companies, including a lumber company and freight line, are located south of the terminal. It is unlikely that there are any substantial quantities of chemical contaminants at the smaller waterfront facilities. Therefore, in evaluating potential nonpoint sources, additional consideration was given to identifying industries potentially contributing to offshore sediment contamination through groundwater contamination.

Metals--Metal contamination in problem area West Waterway I was concentrated in the southwest corner of the waterway (see Figure 4-17). Lead and mercury concentrations exceeded the LAETs at Stations WW-06 (lead=330 mg/kg, mercury=0.492 mg/kg) and S-0036 (lead=310 mg/kg, mercury=0.44 mg/kg) (PTI and Tetra Tech 1988). Mercury contamination was also detected in sediment from Station WW-08, downstream of Station WW-06. Zinc was also a contaminant at Station WW-06 (E344 mg/kg). As discussed earlier, these stations were located near the SW Hinds CSO/SD outfall, but the drain may not be a primary source of metal contamination. The major waterfront facility adjacent to this area is Terminal 5, located on the west side of the waterway. The terminal is currently operated by the Port of Seattle as a shipping, storage, and container handling facility and is served by a private storm drain system. The site was listed as a potential contaminant source by Sweet-Edwards & Associates and Harper-Owes (1985). Soil samples collected by CH2M HILL were found to contain arsenic, copper, lead, nickel and zinc (as reported by Black & Veatch 1985), indicating that some metal contamination may be present at this site.

The potential for metal contamination in offshore sediments by groundwater contamination from other industries in the area was evaluated. No specific sources of lead or mercury were identified. Zinc is a frequent component in metallic coatings and alloys. Brass and bronze account for the third largest usage of zinc. The Zandt Brass Foundry, located west of the waterway, operates a sand casting facility for bronze, brass (copper alloys), aluminum, and iron. A report from an Ecology inspection in May 1987 noted that the entire back lot of the property was filled with sand

from the castings and miscellaneous used material from the foundry (Ecology 1987). A landfill on adjacent Seattle Steel property had also been used by the Zandt Foundry, and contained many rusty 55-gal drums with unknown contents (Ecology 1987). Although the potential for groundwater contamination from this facility exists, there are no data to confirm that lead, mercury, or zinc are present at the site.

The City of Seattle operated a landfill on the west side of the waterway between 1939 and 1966. The facility encompassed approximately 20 ac south of SW Florida St., between SW Harbor Ave. and the railroad tracks. The landfill was used primarily for disposing of municipal waste, but because of its location in an industrial area, it is also suspected to contain industrial wastes (Black & Veatch 1985). Slag from Bethlehem Steel is known to have been deposited at the landfill (Sweet-Edwards & Associates and Harper-Owes 1985). Data collected by Metro as part of the Renton Effluent Transfer Project indicated that soil and groundwater in the vicinity of the landfill contained detectable concentrations of several metals, including lead, mercury, and zinc, but concentrations were relatively low (e.g., lead <0.02-0.055 mg/kg, mercury <0.001 mg/kg, and zinc <0.006-0.489 mg/kg) (Converse Consultants 1985). Based on data from these samples, groundwater from the landfill does not appear to be a major source of metal contamination in the West Waterway.

Bethlehem Steel (now owned by Seattle Steel) operated a slag dump on SW Andover St. between 28th Ave. SW and 26th Ave. SW (Sweet-Edwards & Associates and Harper-Owes 1985). The slag dump operated for a period of about 20 yr and received solids from the contact cooling water treatment system; sulfuric acid pickling liquor wastes; and electroplate, hot dip, and coil pickle process wastes. The slag dump reportedly contains about a 4-ft depth of waste material.

The only other observed metal contamination in the West Waterway I problem area was at an isolated station (WW-02) at the south end of the waterway (see Figure 4-17). Sediments from Station WW-02 (E266 mg/kg) exceeded the LAET for zinc (260 mg/kg) (PTI and Tetra Tech 1988). Zinc does not appear to be associated with waterfront facilities near this station.

The Mono Roofing Company is located inland on the south end of Harbor Island and problems with zinc contamination have been documented at the site (Ecology 1987). Any discharge from Mono Roofing would enter the West Waterway across from Station WW-02, via the SW Spokane CSO/SD (102) (see Figure 4-17).

The Mono Roofing site is used for mixing roofing compounds and transferring the material to trucks and tanks. Until September 1985, these mixtures included an emulsion that contained zinc oxide (Ecology 1987). Ecology conducted onsite investigations and concluded that zinc oxide and/or roofing emulsion from Mono Roofing may have entered the West Waterway. A report from an Ecology inspection conducted in 1985 noted that although there were no storm drains on the property itself, runoff water flowed to two drains located on the adjacent property (Ecology 1987). A water sample from a storm drain near the facility and a soil sample in the vicinity of the drain were collected by Ecology in January 1986, and were found to exceed the Washington State water quality standards for zinc (WAC 173-201) (Cargill, D., 24 February 1986, personal communication). Ecology also investigated a discharge of turbid water to the Duwamish River in November 1986 and found that the material originated at Mono Roofing. Mono Roofing was ordered to suspend all discharge and it was recommended that all washwater and wastewater be reused or pretreated prior to discharge into the sanitary sewer (Ecology 1987). In August 1987, Ecology (Cargill, D., 20 October 1987, personal communication) collected and analyzed stormwater surface runoff from the Mono Roofing yard. The analytical results showed a concentration of 2,320 ug/L of zinc. Effluent from the SW Spokane St. CSO/SD (102) collected on the same day contained 1,180 ug/L of zinc.

Clearly, Mono Roofing has been a source of zinc contamination in the past. Since titanium dioxide has replaced zinc oxide as an emulsion (Ecology 1987), the facility is probably not an ongoing source of zinc contamination. In addition, it should be noted that the zinc contamination observed in the waterway sediments was at Station WW-02, located on the opposite side of the waterway from the Mono Roofing site. The spatial coverage of stations in the offshore sediments is not adequate to clearly distinguish gradients of zinc concentration in this area. Because sediments

from Station WW-01 (see Figure 4-17) did not exhibit any zinc contamination, Mono Roofing cannot be confirmed as the source responsible for zinc contamination in the West Waterway I problem area.

PAHs--PAH concentrations exceeding the HAET were observed in three locations in the West Waterway: Station WW-04, and in the southwest corner of the waterway at Stations WW-06 (PTI and Tetra Tech 1988) and S0036 (Romberg et al. 1984). Elevated concentrations of 1-methylphenanthrene (470 ug/kg), a petroleum indicator (Prah1 and Carpenter 1983), were found in the 16th Ave. SW CSO/SD sediments. Fisher Mills, a flour products and bulgar producer, is located on the waterfront near this station. No major petroleum facilities are located in the area. Small amounts of oil and gasoline for transportation and equipment may be stored on the Fisher site and at other industries in the area, but the potential for contamination from these facilities is low.

The PAH compounds observed at Station WW-06 were distinctly different from those observed at Station WW-04 (PTI and Tetra Tech 1988), indicating a different source of contamination. As discussed earlier, PAH contamination at Station WW-04 was not associated with the nearby SW Hinds CSO/SD. The station is near the Port of Seattle's Terminal 5. Soil samples collected by CH2M HILL identified the south end of the terminal as an area contaminated with oil (as reported by Black & Veatch 1985). Samples contained organic contaminants such as pyrene, fluoranthene, phenanthrene, anthracene, and naphthalene. Total PAH concentrations ranged from 0.02 to 1.5 percent.

The West Seattle landfill, discussed earlier as a possible source of metal contamination, may also have been a source of PAHs. Samples collected by Metro indicated that soils along Harbor Ave. SW contained as much as 0.40 percent PAH (Converse Consultants 1985). Contaminated groundwater from below the landfill may discharge into the West Waterway and contribute to the PAH contamination of offshore sediments.

PCBs--PCB contamination was widespread throughout the West Waterway I problem area. Sediments from six of the seven stations sampled in the present study, and two of the three historical stations, contained PCBs at

concentrations exceeding the LAET (see Table 5-3). It is probable that a large number of facilities in the area have at some time used equipment containing PCBs (see Appendix H).

Other Organic Compounds--Several isolated occurrences of organic compounds were found at stations in the West Waterway I problem area. 2,4-Dimethylphenol was elevated in offshore sediments at Station 12 (Gamponia et al. 1986). Insecticides and fungicides, possibly containing 2,4-dimethylphenol, are used at Fisher Mills. Other potential sources may have contributed to 2,4-dimethylphenol contamination in the offshore sediments. In addition, the elevated concentration of this chemical was not confirmed in nearby sediment samples collected in the present study.

Dimethyl phthalate contamination was observed at Station WW-06. However, replicate laboratory analyses for dimethyl phthalate in the WW-06 sample resulted in very different results: U6.0 ug/kg and E620 ug/kg. Because dimethyl phthalate is commonly found in plasticizers, it is a frequent laboratory contaminant. Although the mean at this station exceeded the HAET (160 ug/kg), it may not accurately indicate sediment contamination.

Stations WW-08 and WW-02 showed elevated levels of benzyl alcohol contamination. Uses of benzyl alcohol are summarized in Appendix H. No specific facilities or sources of this compound were identified in the area.

Summary--

Despite the severe biological effects that characterize the West Waterway I problem area, chemical contamination in the offshore sediments was only moderate (PTI and Tetra Tech 1988). A few localized areas of metal, PAH, and PCB contamination were evaluated for possible source identification. The SW Spokane CSO/SD (102) was the only drain where a relationship between the contaminants (i.e., zinc and PCB) in the receiving environment and drain sediments was observed. Potential nonpoint sources were also evaluated. No definite associations could be made between the industrial facilities in the area and chemical contamination observed in offshore sediments.

5.1.5 West Waterway II Problem Area

The northern section of the West Waterway, Stations WW-09 through WW-18, (see Figure 5-1) was designated a high-priority problem area because of chemical contamination (PTI and Tetra Tech 1988). Although concentrations of several chemicals were elevated in the waterway sediments, the lead contamination along the east side of the waterway distinguishes this problem area from rest of the West Waterway. Other problem chemicals identified in the sediments of the West Waterway II problem area included PAH compounds, p,p'-DDT, p,p'-DDD, and dimethyl phthalate (see Table 5-3). Analyses of sediment samples collected by Gamponia et al. (1986) identified three additional chemicals exceeding HAETs: copper, PCBs, and 2,4-dimethylphenol.

Lead concentrations in the West Waterway II problem area exceeded problem area the HAET (700 mg/kg) at four stations along the east side of the waterway. Station WW-14, located adjacent to the SW Lander CSO/SD (105) and SW Lander SD (see Figure 4-17) had a lead concentration of 8,730 mg/kg. Station 9, located nearby, exhibited a similarly high lead concentration of 10,600 mg/kg (Gamponia et al. 1986). Lead concentrations in the sediment decreased moving south, but still exceeded the HAET at Stations WW-12 (1,180 mg/kg), WW-11 (721 mg/kg) and WW-09 (708 mg/kg). Lead was not identified as a problem chemical at stations located on the west side of the waterway.

Concentrations of PAH compounds were generally elevated over most of the West Waterway II problem area. Four stations exceeded the HAET for HPAH (38,000 ug/kg). Nine of the ten stations sampled in the present study contained sediments with concentrations of LPAH or HPAH that exceeded LAET (5,200 and 12,000 ug/kg, respectively). Concentrations of HPAH compounds were highest on the east side of the waterway and ranged from 20,00 to 40,000 ug/kg.

Additional contaminants exceeding the HAET concentrations were observed in localized areas. p,p'-DDD was measured at 80 ug/kg (HAET=43 ug/kg) at Station WW-09, but was undetected at adjacent stations. Dimethyl phthalate

exceeded the HAET (160 ug/kg) at Stations WW-09 and WW-13 (PTI and Tetra Tech 1988).

Additional areas of chemical contamination were identified based on historical samples (PTI and Tetra Tech 1988). Gamponia et al. (1986) measured a copper concentration of 860 mg/kg (HAET=800 mg/kg) at Station 9, located on the east side of the waterway (see Figure 4-17). Lead and zinc also exceeded the HAET at this station. Gamponia et al. (1986) described PCB concentrations in the area ranging from 2,300 to 3,700 ug/kg. However, PCB levels in the present study and from other historical data were typically 1 order of magnitude lower. While Gamponia et al. (1986) reported concentrations ranging from 500 to 800 ug/kg, 2,4-dimethylphenol was undetected at nearby stations in this study (PTI and Tetra Tech 1988).

Elevated concentrations of two other chemicals in this problem area should be noted, although they were not identified as problem chemicals using AETs. Both antimony and chromium were observed at elevated concentrations in the West Waterway II problem area. The concentration of chromium at Station WW-12 (see Figure 4-17) (E555 mg/kg) exceeded the 90th percentile concentration. Concentrations at the adjacent stations (Stations WW-14 and WW-09) were less than 200 mg/kg. Other chromium concentrations in the study were within the range of reference area values (PTI and Tetra Tech 1988). Similarly, the two highest concentrations of antimony observed in the study were located in this problem area (1,370 mg/kg at Station WW-14 and 1,160 mg/kg at Station WW-12) (PTI and Tetra Tech 1988). Because of the likelihood that analytical methods used to generate the AETs for chromium and antimony are not directly comparable to the methods used in historical studies, these AETs were not used to identify problem chemicals (PTI and Tetra Tech 1988).

Potential Contaminant Sources--

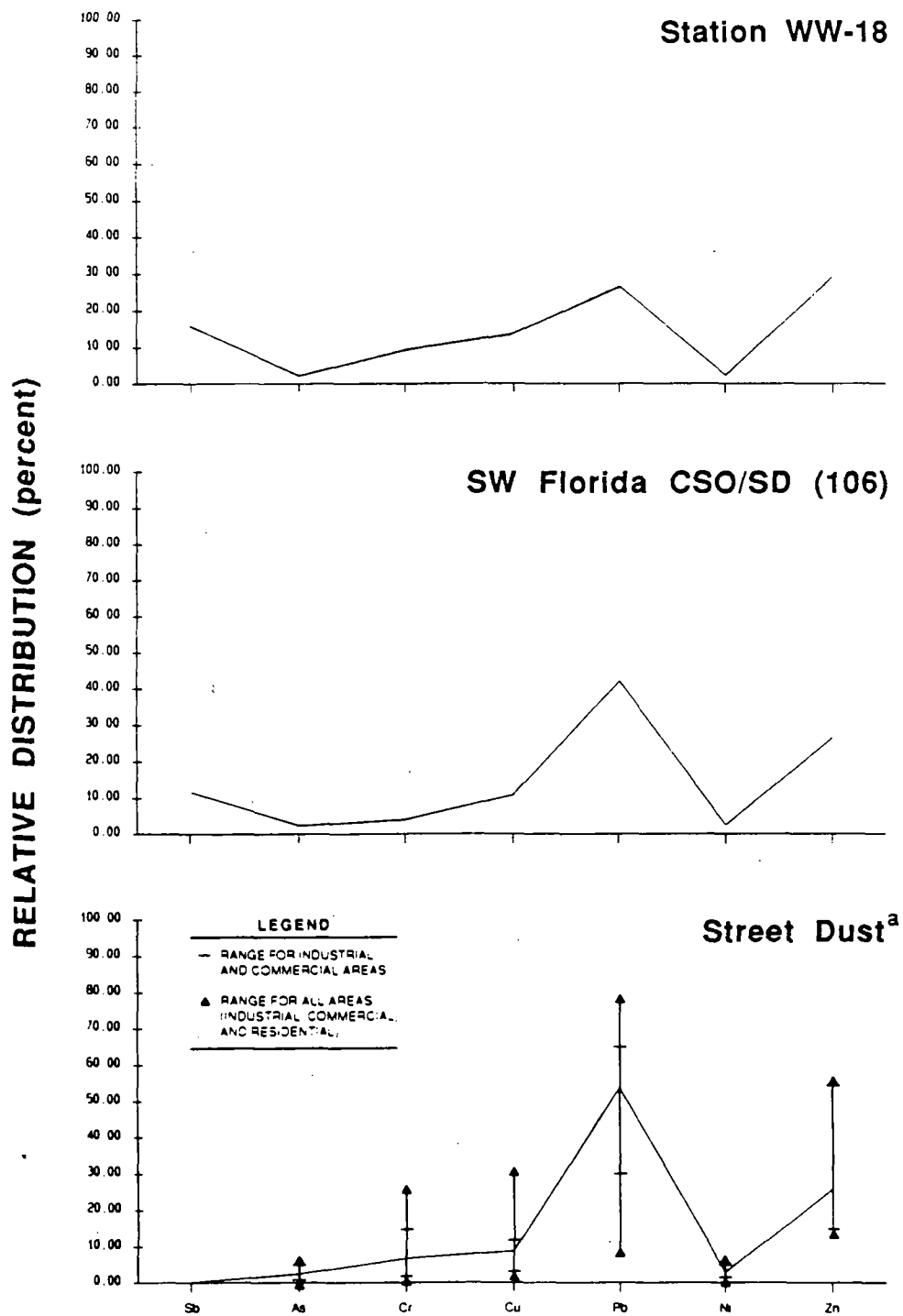
In the West Waterway II problem area, elevated chemical concentrations in the offshore sediments exhibited two different spatial patterns, suggesting different sources. Metal contamination was concentrated along the east side of the waterway. This distribution suggests one or more local

sources. In contrast, PAH contamination was widespread and generally elevated throughout the area. The absence of a clear spatial trend indicates multiple sources. In the following discussion, chemical contamination potentially resulting from CSO/SD discharges will be evaluated first, followed by a more general discussion of potential nonpoint sources.

Sediment samples were collected from four drains in the West Waterway II problem area: SW Florida CSO/SD (106), SW Lander SD (21 in), SW Lander CSO/SD (105) and SW Florida CSO/SD (098). The results of chemical analysis of sediment collected from these drains and sediments collected from the nearest offshore station were compared to evaluate the potential contribution of the drain to offshore contamination.

SW Florida CSO/SD (106)--Two problem chemicals, lead (804 mg/kg) and benzoic acid (E2,500 ug/kg), were identified in the SW Florida CSO/SD (106). The offshore station closest to the CSO/SD outfall was Station WW-18 (see Figure 4-17). At Station WW-18, indeno (1,2,3-c,d) pyrene (E1,000 ug/kg) exceeded the HAET concentrations, and dibenzo(a,h)anthracene (EX310 ug/kg) and fluoranthene (1,800 ug/kg) exceeded the LAET concentrations. Lead (339 mg/kg), mercury (1.63 mg/kg), zinc (368 mg/kg), PCBs (270 ug/kg), and p,p'-DDD (11 ug/kg) concentrations in the offshore sediments also exceeded the LAETs (PTI and Tetra Tech 1988).

A comparison of the relative distribution of metals in sediments from the SW Florida CSO/SD (106), Station WW-18, and street dust is shown in Figure 5-13. The relative distribution of metals in the sediment from Station WW-18 was similar to that of the sediment from the SW Florida CSO/SD (106), with antimony, lead, and zinc having the greatest relative abundances. The relative distribution of metals in street dust also matched that of the two sediments relatively well, with the exception of antimony. However, the antimony data may be elevated by a factor of 4-5 due to the analytical procedure used in this study (see Section 3.2.4). Antimony is not typically found in street dust. The SW Florida CSO/SD (106) could have been a source of the metals contamination at Station WW-18.



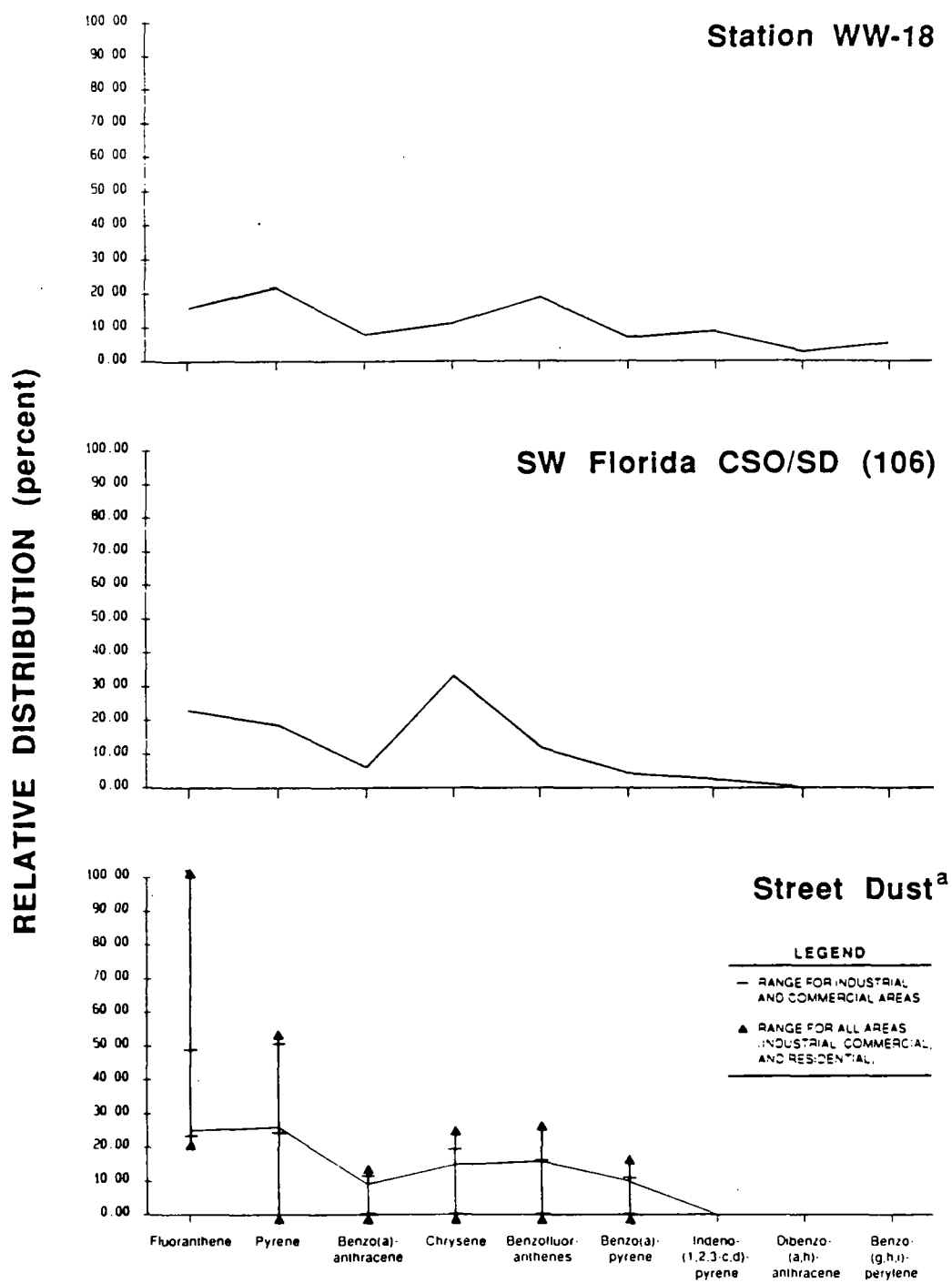
^a Reference: Galvin and Moore (1982).

Figure 5-13. Comparison of relative percent distribution of metals in offshore sediment from West Waterway II problem area and a nearby drain.

A comparison of the relative distribution of HPAH compounds in the CSO/SD and offshore Station WW-18 is presented in Figure 5-14. These relative distributions do not match each other well. The relative abundance of chrysene was 3 times higher in the drain sediment than in the offshore sediment, and neither dibenzo(a,h)anthracene nor benzo(g,h,i)perylene were found in the drain sediments. In addition, the concentration of HPAH in the sediment from Station WW-18 (E11,420 ug/kg) was greater than the concentration of HPAH in the sediment from the drain (E9,696 ug/kg). Based on these results, the SW Florida CSO/SD (106) could not be linked to the HPAH contamination in the sediments at Station WW-18.

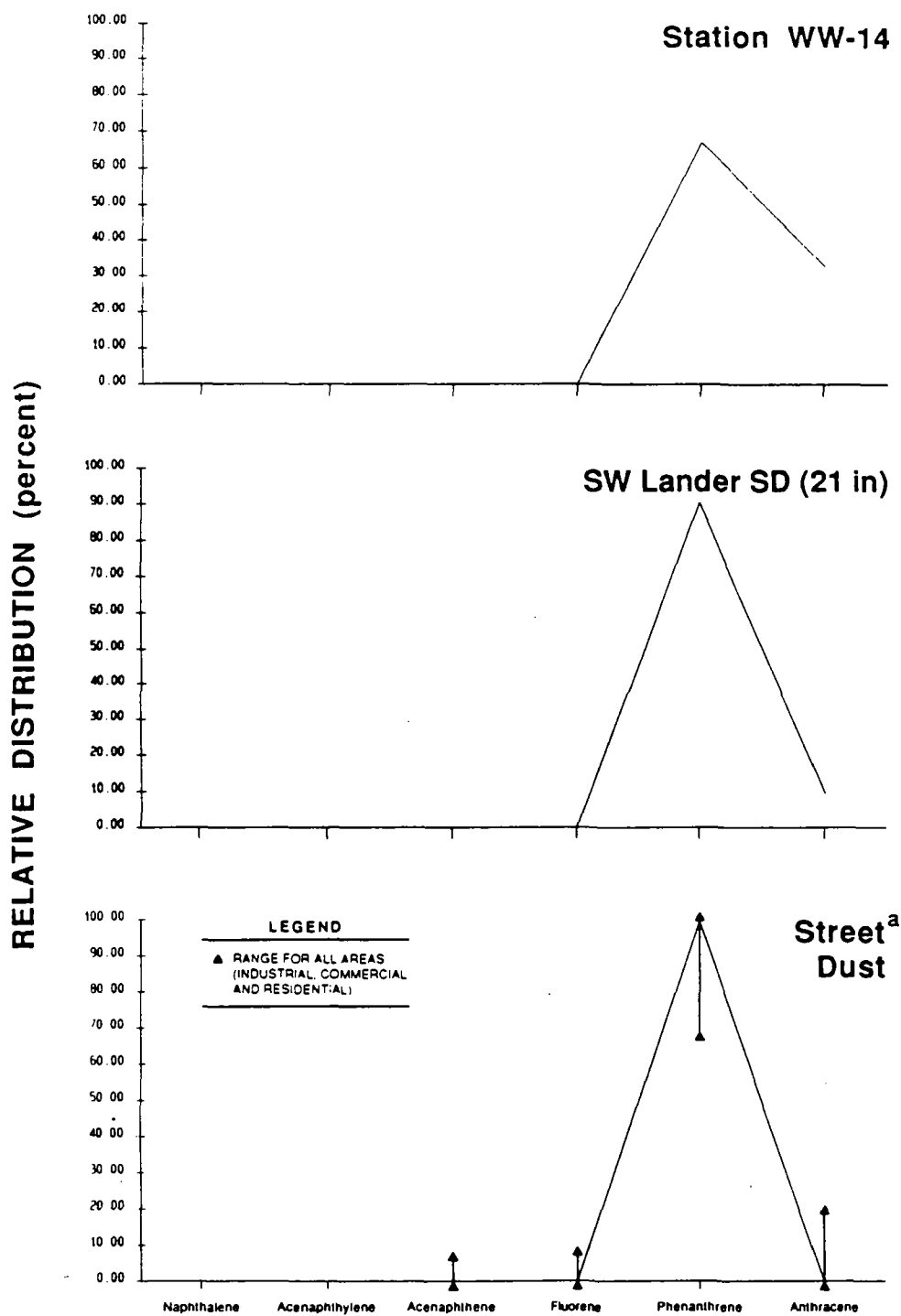
SW Lander SD (21 in)--The SW Lander SD is a private storm drain that served the property on the north side of SW Lander St. between 16th Ave. SW and 13th Ave. SW. This storm drain is no longer in operation. No problem chemicals were identified in the SW Lander SD sediment sample. In sediments collected from the offshore station closest to the SW Lander SD (Station WW-14; see Figure 4-17), one HPAH compound [indeno(1,2,3-c,d)pyrene, (E1,100 ug/kg)] and lead (8,730 mg/kg), exceeded the HAET. Total HPAH (31,000 ug/kg), PCBs (380 ug/kg), mercury (E1.12 mg/kg) and zinc (E431 mg/kg) exceeded the LAETs (PTI and Tetra Tech 1988).

The relative distribution of LPAH compounds in the sediments from the SW Lander SD and Station WW-14 sediments are compared in Figure 5-15. Phenanthrene and anthracene were the only LPAH compounds found in both the Station WW-14 sediment and the drain sediment. The relative abundances of both compounds fall within the range of concentrations found in street dust, but the combined concentration of these two compounds was much greater in the sediment from Station WW-14 (E1,830 ug/kg) than in the sediment from the SW Lander SD (21 in) (E309 ug/kg). The relative distributions of HPAH compounds found in the drain and offshore sediments were similar (Figure 5-16). The relative abundances of these compounds, with the exception of indeno(1,2,3-c,d)pyrene, were within the ranges found in street dust. However, the concentration of HPAH was much greater in the sediment from Station WW-14 (E30,900 ug/kg) than in the sediment from the drain (E1,333 ug/kg). Based on these results, the SW Lander SD (21 in) could not be linked to the contamination observed at Station WW-14.



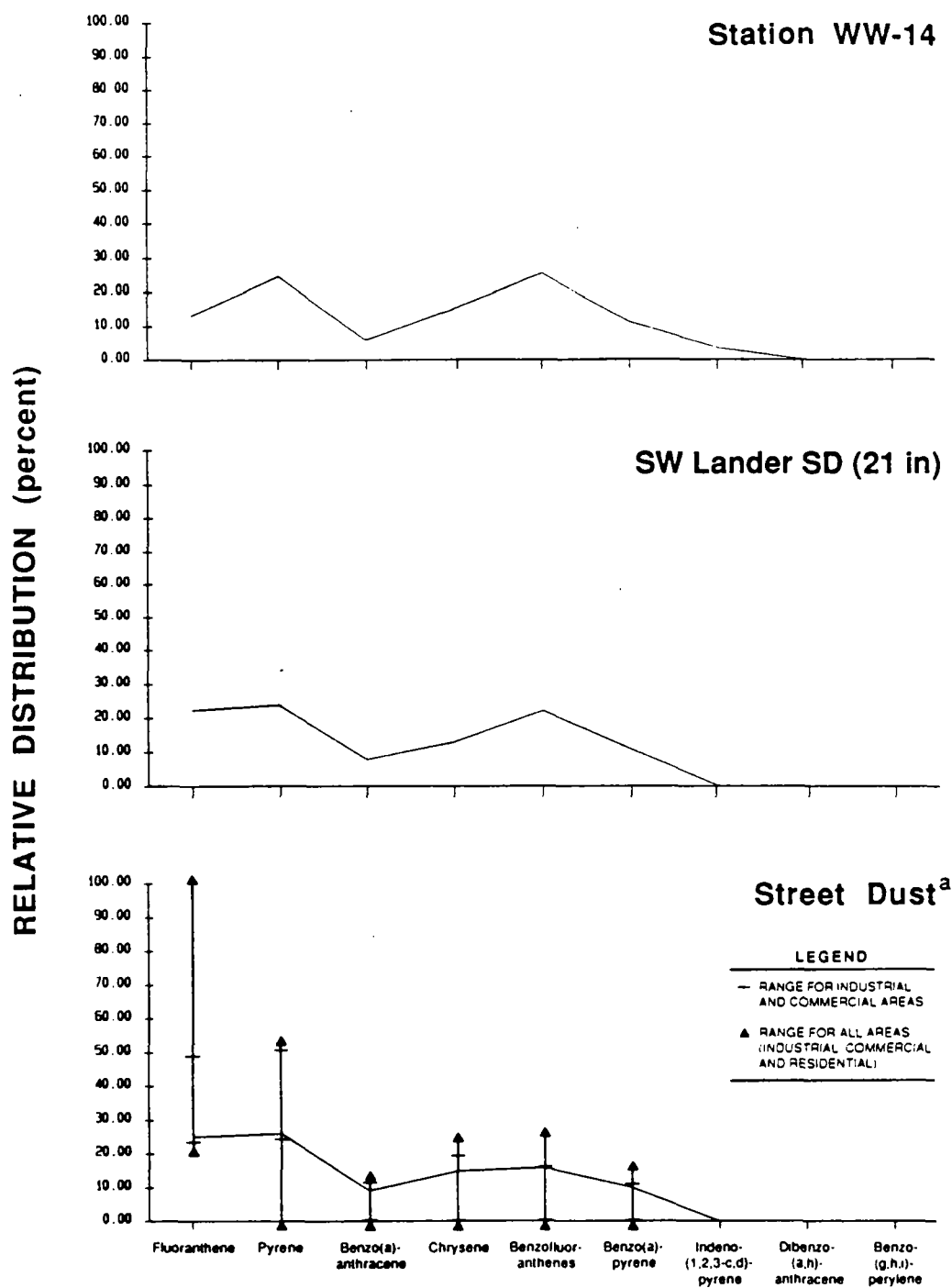
^a Reference: Galvin and Moore (1982).

Figure 5-14. Comparison of relative percent distribution of HPAH in offshore sediment from West Waterway II problem area and a nearby drain.



^a Reference: Galvin and Moore (1982).

Figure 5-15. Comparison of relative percent distribution of LPAH in offshore sediment from West Waterway II problem area and a nearby drain.



^a Reference: Galvin and Moore (1982).

Figure 5-16. Comparison of relative percent distribution of HPAH in offshore sediment from West Waterway II problem area and a nearby drain.

Mercury (E0.057 mg/kg) and zinc (E255 mg/kg) did not exceed the LAET in the SW Lander SD sediment. PCBs were not detected in the SW Lander SD sediment at a detection limit of 220 ug/kg. The SW Lander SD could not be linked to the PCB contamination observed at Station WW-14.

SW Lander CSO/SD (105)--Lead (52,800 mg/kg) was the only problem chemical identified in the SW Lander CSO/SD (105) based on HAET comparisons. Two additional chemicals, antimony (3,930 mg/kg) and xylene (E187 ug/kg), exceeded the 90th percentile concentrations. The SW Lander CSO/SD (105) discharges immediately adjacent to the SW Lander SD (21 in). Offshore Station WW-14 is in close proximity to both these drains (see Figure 4-17). HPAH and lead concentrations at this offshore station exceeded the HAET, and concentrations of LPAH, PCB, mercury, and zinc exceeded the LAET.

The lead concentration (52,800 mg/kg) in the SW Lander CSO/SD (105) sediment was by far the highest concentration reported during this source investigation and was over 1 order of magnitude greater than the concentration of lead in industrial/commercial street dust (380-1,100 mg/kg). The estimated average annual flow from the SW Lander CSO/SD (105) (50 Mgal/yr) is more than 6 times greater than the estimated flow from the SW Lander SD (21 in) (8 Mgal/yr). The high lead concentration in the sediment, combined with the high flow, indicate that the SW Lander CSO/SD (105) was a major source for lead contamination observed in offshore sediments. Lead contamination in the SW Lander CSO/SD (105) has been attributed to emissions from a secondary lead smelter that operated in the Lander basin between 1937 and 1984 (Hubbard and Sample 1988), and is discussed in Section 4.3.

The SW Lander CSO/SD (105) sediment contained the highest concentration of xylene observed in all the Elliott Bay drain samples (E187 ug/kg), but xylene was not found in the sediments from Station WW-14. Detectable concentrations of xylene may not have been found in the offshore sediment sample because of the volatile nature of this chemical. The relatively high concentration of xylene in the SW Lander CSO/SD (105) sediment indicates that the drain may discharge substantial quantities of the chemical. Water

samples from the drain analyzed for volatile organics would provide more information about potential loading of contaminants in the waterway.

PAH concentrations in the SW Lander CSO/SD (105) (LPAH=E1,088 ug/kg; HPAH=E3,986 ug/kg) were less than the concentrations measured at offshore Station WW-14 (LPAH=E2,800 ug/kg; HPAH=31,000 ug/kg); therefore, a definitive relationship between contamination in the drain and receiving environment could not be demonstrated.

SW Florida CSO/SD (098)--No problem chemicals were identified in the SW Florida CSO/SD (098) sediment. The offshore station in closest proximity to the drain was Station WW-17 (see Figure 4-17). One HPAH compound [indeno(1,2,3-c,d)pyrene, E1,800 ug/kg] exceeded the HAET concentration at this station. Total HPAH (E19,000 ug/kg), PCBs (E360 ug/kg), dimethyl phthalate (E99 ug/kg), mercury (E0.716 mg/kg), and zinc (E297 mg/kg) exceeded the LAETs. As discussed in Section 4.3, samples analyzed by Metro in 1984 indicated that this drain was highly contaminated with arsenic, copper, PAH, PCBs and pentachlorophenol. Wyckoff's West Seattle wood treatment facility and a scrap yard that had recycled transformers containing PCBs, were identified as the sources of these contaminants (Hubbard and Sample 1988). The SW Florida CSO/SD was cleaned 1 yr prior to the sediment sampling effort, so the absence of problem chemicals observed in the current samples was not unexpected. Metro resampled one of the catch basins on the Wyckoff property in March 1986 and found that the sediments were again contaminated with HPAH (106,700 ug/kg), LPAH (22,300 ug/kg), and pentachlorophenol (1,740 ug/kg) (Sample, T., 27 March 1987, personal communication). The contamination was believed to be associated with stormwater runoff from the Wyckoff property. It is probable that the CSO/SD is an ongoing source of contamination.

Comparisons of the relative distributions of PAHs in sediments from the SW Florida CSO/SD (098), in sediments collected at Station WW-17, in sediments from a catch basin upstream of the SW Florida CSO/SD (098), and in street dust are shown in Figures 5-17 and 5-18. The relative distribution of LPAH in the sediment from Station WW-17 matches that of the sediment from the SW Florida CSO/SD (098) and, to a lesser extent, that of the sediments

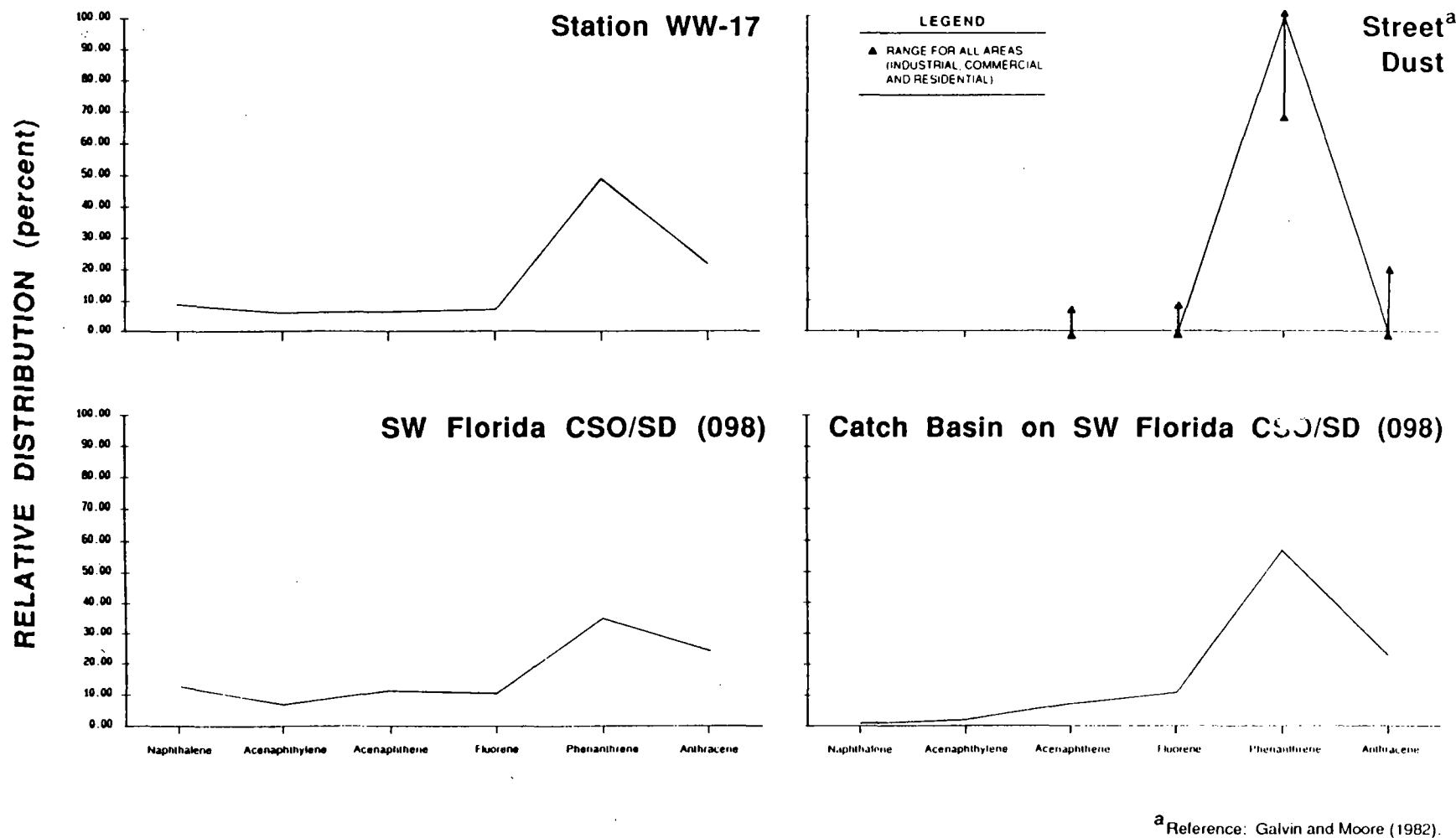
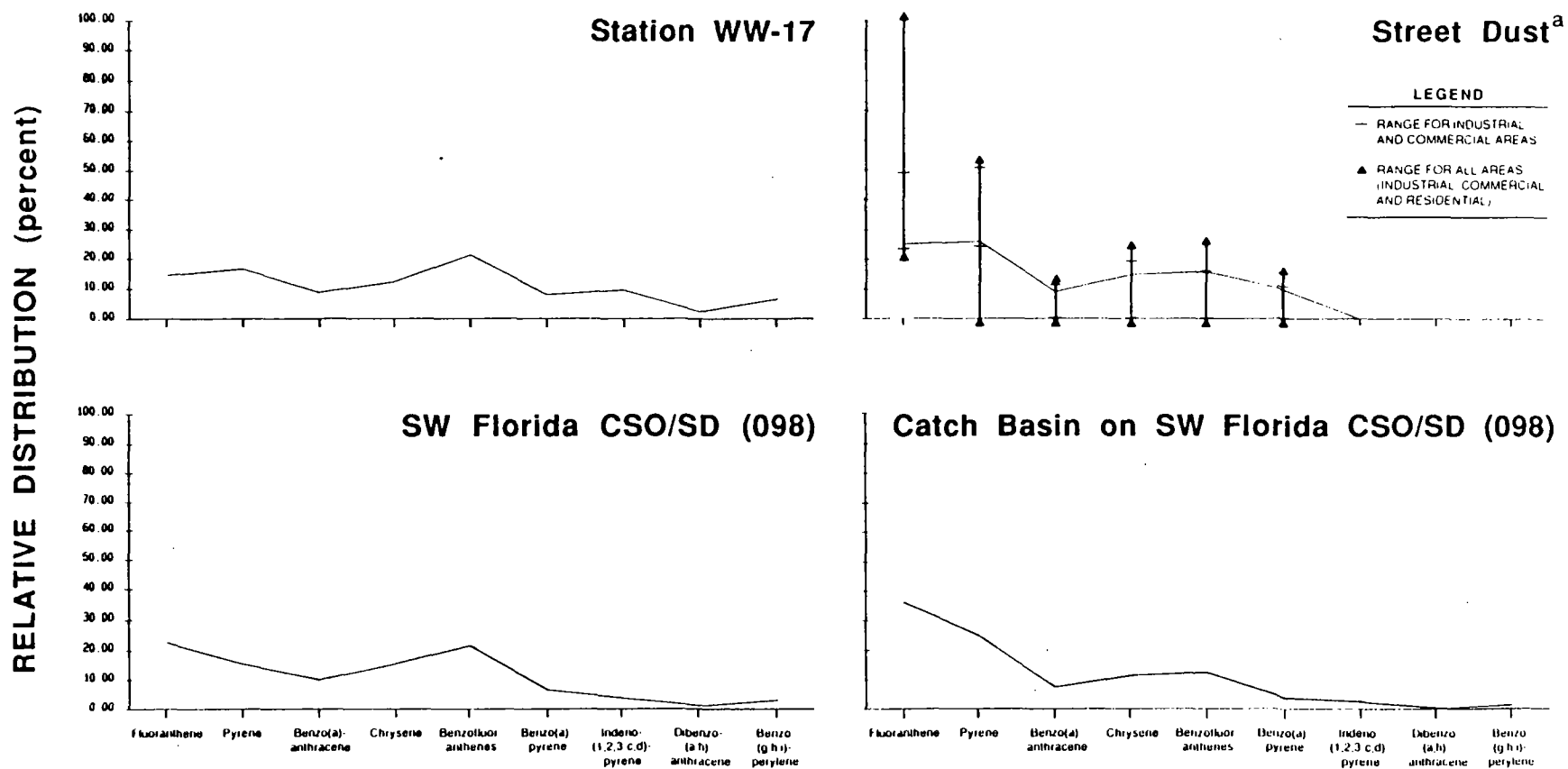


Figure 5-17. Comparison of relative percent distribution of LPAH in offshore sediment from West Waterway II problem area and a nearby drain.



^aReference: Galvin and Moore (1982).

Figure 5-18. Comparison of relative percent distribution of HPAH in offshore sediment from West Waterway II problem area and a nearby drain.

from the catch basin. The presence of naphthalene, acenaphthylene, acenaphthene and fluorene in the drain and offshore sediments suggests that street dust was not the only source of LPAH contamination at Station WW-14.

The relative distributions of HPAH compounds in the three sediments also agree relatively well (see Figure 5-18), although the concentration of HPAH in the offshore sediment (E18,640 ug/kg) was much greater than the concentration of HPAH in the sediment from the SW Florida CSO/SD (098) (E3,550 ug/kg). This difference may be because the contaminated sediments were removed from the SW Florida CSO/SD (098) by the City of Seattle in 1985. Sediments from a catch basin farther upstream in the drain were recontaminated (Sample, T., 27 March 1987, personal communication), but this contamination may not have been reflected in the sample collected near the mouth of the drain.

Lockheed Shipbuilding Company--The Lockheed Shipbuilding Company's Yard I, located south of SW Lander St., occupies more than half of the eastern shoreline of the West Waterway II problem area (see Figure 4-17). The facility began operation in the late 1950s, but was closed in November 1986 and is now for sale (Seattle Times 1988). Runoff from the site drains to the waterway through a private storm drain system (see Figure 4-11). Although the area offshore of the Lockheed facility was the site of dredging and construction activity in 1975 (see Figure G-5 in Appendix G), many contaminants were identified in samples from stations in this vicinity. All the offshore stations (WW-09, WW-11, WW-12) in this area exceeded the HAET for lead and the LAET for mercury, zinc, and PCBs (see Table 5-3). In addition, Station WW-12, located near one of the Lockheed drydocks, exceeded the LAETs for arsenic and copper, and the 90th percentile concentration for chromium. Station 9 (Gamponia et al. 1986) was also located near a Lockheed drydock. Both copper and lead concentrations exceeded the HAET at this station, and zinc and mercury exceeded the LAET.

The shipbuilding industry uses a number of processes and materials containing these chemical contaminants (e.g., sandblasting grit, paint, and solvents). Sandblasting grit is used to clean steel and may be a source of metal contamination (see Section 4.3). Many shipyards in the Puget Sound

region used slag from a copper smelter in British Columbia (Dexter et al. 1981) or from the ASARCO smelter in Tacoma as sources of sandblasting grit. In the past, spent sandblast material was released to the waterways when drydocks were flooded. In addition, fugitive dust emissions from upland sandblast activities probably entered the waterway via stormwater runoff. Deep deposits of sandblast grit were observed in the intertidal sediments adjacent to the Lockheed drydocks (Tetra Tech 1987c). Sources of the sandblast grit used by Lockheed are unknown, but are likely one of the two smelters mentioned above. The relative distribution of metals in ASARCO slag, in sediments collected near other shipyards, and in sediments from stations adjacent to Lockheed (Stations WW-09 and WW-12) are plotted in Figure 4-39. With the exception of arsenic, the distributions are very similar, indicating that past sandblasting activity at the shipyard may have been a major contributor to metal contamination on the east side of the West Waterway. A report from an Ecology inspection in 1985 (Ecology 1987) indicated that sandblasting operations at the Lockheed facility had been contained and the residue was being collected and sent to a cement manufacturer.

Marine paints may also be a source of metal contaminants (Bellinger and Benham 1978). Chromium, lead, and zinc are major constituents of primer paints (Young et al. 1979). The Lockheed shipyard used lead-based paints in the past, but their use was discontinued in 1966 (Harper-Owes 1983). Until 1975, various mercury compounds were often used as antifoulants in marine paint. Copper is now the most frequently used antifouling agent and constitutes a potentially substantial source of this metal to the marine environment (Young et al. 1979). Zinc is used in anti-corrosion paint pigments and in sacrificial anodes attached to boat hulls (Muehling 1987; Young et al. 1979). In addition, prior to 1972, PCBs were used in paints and hydraulic fluids (Young et al. 1979). Until the implementation of an overspray control device, paint overspray from the Lockheed facility was deposited into the river (Tetra Tech 1986b).

Concentrations of zinc, mercury, and PCBs exceeded the LAET at all stations on the east side of the waterway. Station WW-12 and Station 9 (Gamponia et al. 1986), adjacent to Lockheed drydocks (see Figure 4-17),

also exceeded the HAET for copper and Station WW-12 exceeded the 90th percentile concentration of chromium. All these elevated metals are associated with shipyard activities.

Turpentine and paint thinner are common solvents used by shipyards. Marine paints contain approximately 35 percent solvent by weight (Muehling 1987). Xylene accounts for 20 percent of the solvents used in the production of commercial marine paints (Muehling 1987). Elevated xylene concentrations were found in sediments from Station WW-11 (see Figure 4-17) and the SW Lander CSO/SD (105).

ARCO--ARCO operates a bulk petroleum storage facility and distribution terminal on the east side of the West Waterway, north of SW Lander St. (see Figure 4-17). Offshore Stations WW-14 and WW-18 are located adjacent to the ARCO site. Although both stations are near CSO/SDs, the drains were not identified as a major source of contamination observed in the offshore sediments discussed earlier in this section.

Hazardous substances associated with the petroleum industry under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) include leaded bottoms from petroleum storage tanks and American Petroleum Institute (API) separator sludge. Improper handling and disposal of tank sludge or sand and sediment from the separators can result in contamination by lead, petroleum products (PAH), and additives such as xylene (50-60 percent of xylene production goes to gasoline), lubricants, dyes, and antioxidants.

Ecology has identified the ARCO facility as a potential source of lead from sandblast material stored onsite (Cargill, D., 19 August 1988, personal communication). An EP toxicity test on the sandblast material yielded 3 mg/L lead. Runoff from the site is discharged to the West Waterway via six private storm drains. The two drains serving the tank farm are routed through oil/water separators. The remaining four drains serve roadways and parking areas on the property.

Total HPAH concentrations exceeded the HAET at both Stations WW-14 and WW-18, but several observations indicate that these contaminants may not have been derived from petroleum sources. The MP/P ratio (an indicator of fossil and combustion derived phenanthrene) at Stations WW-14 and WW-18 was very low (less than 0.2), indicating a combustion-related source of PAHs. The individual HPAH compound, exceeding the HAET (800 ug/kg) at both Stations WW-14 and WW-18, was indeno(1,2,3-c,d)pyrene. The concentration of this chemical at Stations WW-14 and WW-18 was E1,100 ug/kg and E1,000 ug/kg, respectively. This is nearly 1 order of magnitude higher than that observed at other stations in the waterway (Stations WW-16=U100 ug/kg, WW-12=U390 mg/kg, and WW-13=E220 ug/kg). Indeno(1,2,3-c,d)pyrene is not a component of street dust, but has been identified as a product of coal and wood combustion (Lee et al. 1977).

The source of these combustion-related PAH compounds has not been identified and may be related to past activities. Despite its waterfront location, ARCO does not appear to be a current source of PAH contamination. Reports from Ecology inspections conducted in 1986 and 1987 indicated that the ARCO facility was well-maintained and the operation received a satisfactory rating (Ecology 1987).

Other Potential Sources--Stations on the west side exhibited fewer HAET exceedances, compared to stations on the east side of the waterway. The historical contamination of the Florida CSO/SD (098) and the industries contributing to arsenic, copper, PAH, pentachlorophenol, and PCB contamination have been discussed (see Section 4.3). This historical contamination appears to be reflected only slightly in the offshore sediments sampled in the present study. PAH and PCB concentrations exceed the LAET at Station WW-17 located nearest the CSO/SD outfall. However, this area has been the site of dredge and fill and construction activity (see Figure G-5 in Appendix G), and it is possible that the sediments currently deposited in this location may not reflect past contaminant concentrations. This is also true of Station WW-15, where no chemicals exceeded LAET, although phenol exceeded the 90th percentile concentrations (see Table 5-3). At Station WW-13, only dimethyl phthalate exceeded the HAET concentrations.

Terminal 5 is located on the west side of the waterway and is served by a private storm drain system. It is currently operated by the Port of Seattle as a shipping, storage, and container-handling facility. The facility was listed as a potential groundwater contaminant source due to past activities in Sweet-Edwards & Associates and Harper-Owes (1985). Contamination at Terminal 5 is associated with historical land-use activities. The site was investigated by CH2M HILL and numerous soil samples were analyzed (as summarized in Black & Veatch 1985). The investigation identified two problem areas: the south end due to oil contamination, and the north end contaminated with various industrial wastes. Samples indicated the presence of detectable concentrations of organic contaminants in the soil such as pyrene, fluoranthene, phenanthrene, anthracene, and naphthalene. Total PAH concentrations ranged from 0.02 to 1.5 percent (Black & Veatch 1985). Station WW-13, located adjacent to the terminal, exceeded the LAETs for both HPAH (E12,372 ug/kg) and LPAH (E3,819 ug/kg).

PCB concentrations exceeded the LAET (130 ug/kg) at 11 of the 13 stations in the West Waterway II problem area (see Table 5-3). PCB contamination was observed in sediment at over half of the offshore stations. It is probable that a number of facilities on Harbor Island and West Seattle have had equipment containing PCBs, but there should not be ongoing sources of PCBs in the area.

Summary--

In West Waterway II problem area, chemical contamination in the offshore sediments exhibited two general spatial trends 1) metal contamination that is concentrated on the east side of the waterway, and 2) generally elevated concentrations of PAH and PCBs throughout the area. This evaluation of potential sources indicates that the secondary lead smelter located on Harbor Island was the potential primary source for lead contamination in the SW Lander CSO/SD (105) and in sediments on the east side of the waterway. The Lockheed shipyard was the probable source for the remainder of the metal contamination on the east side of the waterway. Sources of PAH and PCB contamination are more diverse and specific sources could not be identified.

5.2 PROBLEM STATIONS OUTSIDE PROBLEM AREAS

5.2.1 Problem Station NS-01

Station NS-01 was an intertidal station located north of Pier 70 on the Seattle north shoreline, less than 250 ft from the Denny Way CSO (W027) outfall (see Figure 4-7). This station was designated as a problem station primarily because of biological indicators of contamination. Sediments from this station received the maximum possible score (100 percent) for biological effects, and a more moderate score (62 percent) for sediment chemistry (PTI and Tetra Tech 1988).

Silver (E8.27 mg/kg) exceeded the HAET concentration at Station NS-01. No other chemicals at this station exceeded any AET or 90th percentile concentrations. Analysis of two nearby historical stations have shown silver at concentrations exceeding HAET. LPAH, HPAH, PCB, mercury, and p,p'-DDT (or its related breakdown products) have been detected at other nearby historical stations at concentrations exceeding HAET (PTI and Tetra Tech 1988). Romberg et al. (1987) reported exceedances of AETs for metals including zinc, mercury, lead, and cadmium at other stations in the proximity of the CSO outfall.

The only drain near Station NS-01 is the Denny Way CSO (W027). Analysis of the sediment from the Denny Way CSO (W027) showed silver (E6 mg/kg), mercury (E3.22 mg/kg), and 1-methylphenanthrene (E450 ug/kg) to be problem chemicals (see Table 4-1). All three of these substances exceeded the HAET for Puget Sound.

The relative distribution of metals in the Denny Way CSO sediment was similar to the relative distribution of metals in the NS-01 sediment, with copper, lead, and chromium constituting approximately 99 percent of the metals evaluated in both sediments (Figure 5-19). The relative distribution of LPAH in the two sediments was also similar, with phenanthrene the major LPAH compound present (Figure 5-20). The relative distribution of HPAH did not match as well as LPAH, with several HPAH compounds in the NS-01 sample undetected at detection limits less than 10 ug/kg (see Figure 5-20).

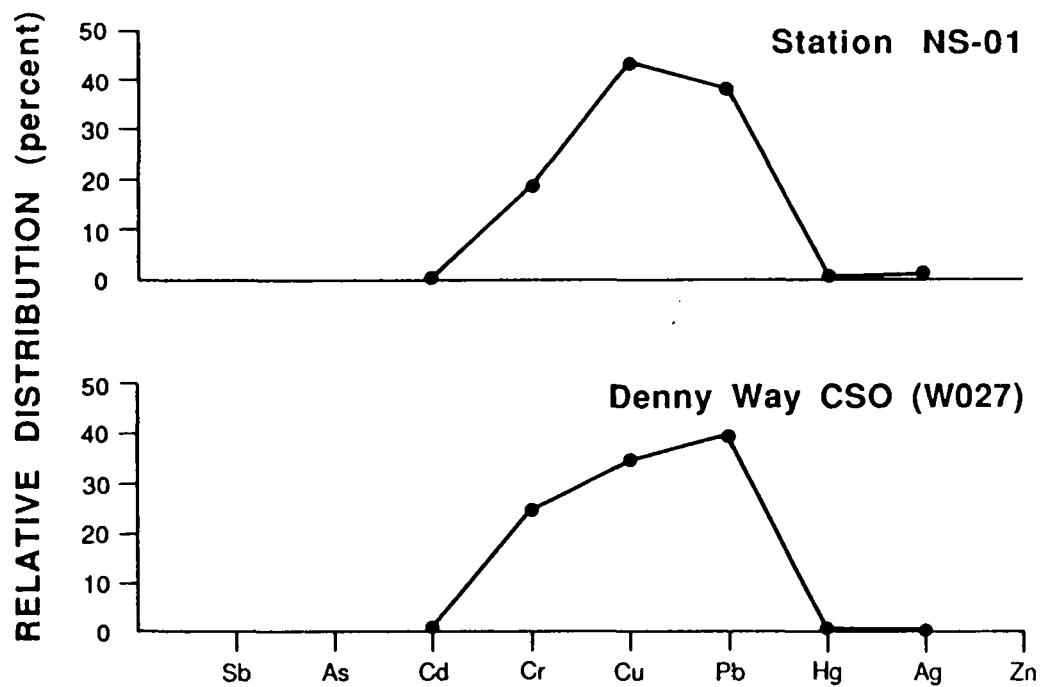


Figure 5-19. Comparison of relative percent distribution of metals in sediment from Station NS-01 and sediment from a nearby drain.

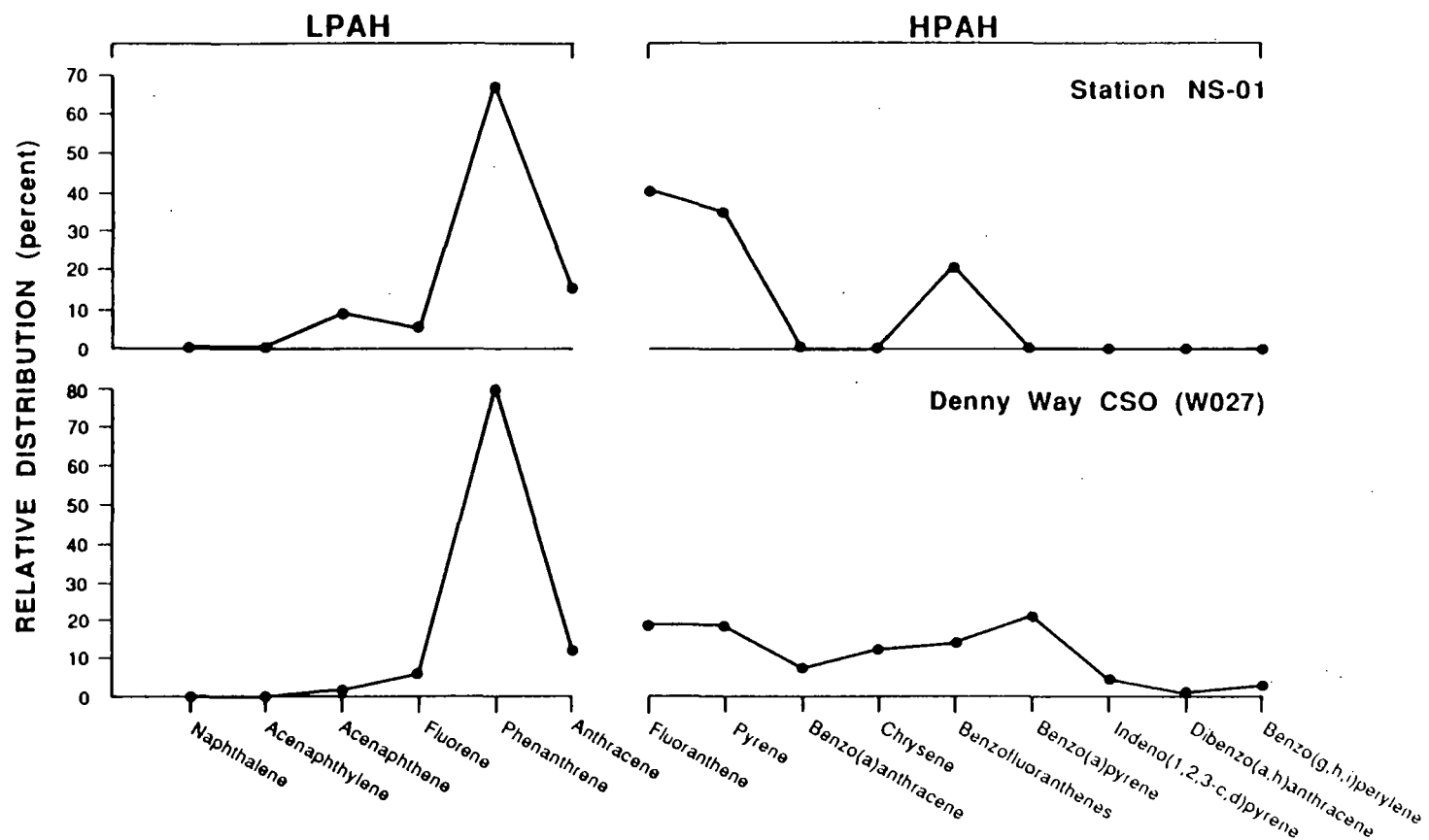


Figure 5-20. Comparison of relative percent distribution of LPAH and HPAH compounds in sediment from Station NS-01 and sediment from a nearby drain.

Given the close proximity of the Denny Way CSO to Station NS-01, the identification of silver as a problem chemical at both locations, and the similarities in relative distribution of chemicals in both sediments, it is likely that the Denny Way CSO (W027) contributed to the silver contamination at Station NS-01.

The Denny Way CSO is the largest and most frequent overflow site on Elliott Bay. There are approximately 530 companies in the CSO service area that could be considered potential contaminant sources (Romberg et al. 1987). These companies include dry cleaners, print shops, photo processors, medical laboratories, auto repair shops, and a variety of light manufacturing facilities. Results from Metro's investigation (Romberg et al. 1987) of contaminant sources in the Denny Way combined sewer system indicated that only a portion of the companies in the area discharge anything other than sanitary sewage flow. Furthermore, the total nonsanitary flow from these companies is estimated to be only 4 percent of the combined average base flow for the Denny local and Denny Lake Union drainage basins (12.6 Mgal/day) (Romberg et al. 1987).

Approximately 25 percent of the 138 printers and 94 graphic and photographic shops in the basin discharge less than 50 gal/day into the Denny Way combined sewer system (Romberg et al. 1987). These discharges may include small amounts of photographic waste, such as developer, which contains only organic compounds (Romberg et al. 1987). According to Metro, these printing and photographic facilities currently either conduct silver reclamation onsite or send spent fixer solutions out for reclamation (Romberg et al. 1987). However, these facilities may have been substantial contributors of silver in the past before silver reclamation was begun.

There are two industrial laundries in the Denny Way service area that each discharge an average of approximately 100,000 gal/day (Romberg et al. 1987). These facilities currently discharge under Metro industrial waste permits that limit the amount of metals and oil and grease discharged. During the 1986 Metro study (Romberg et al. 1987), sediment deposits in the Denny Lake Union Tunnel, which is located a short distance downstream from an

industrial laundry, were discovered to be several feet deep and tapered down to less than 1 ft deep in the first 700 ft of the tunnel. The metal concentrations in these accumulated sediments exceeded the HAET in all cases: cadmium [151 mg/kg wet-weight (WW)], nickel (1,570 mg/kg WW), lead (8,520 mg/kg WW), zinc (5,360 mg/kg WW), and mercury (94 mg/kg WW). The concentrations observed for zinc, lead, nickel, copper, and cadmium were all 4-6 times higher than metal concentrations observed at a site further downstream in the Denny Lake Union Tunnel, while the chromium concentration was twice as high.

Both laundries installed new pretreatment equipment in 1986 to reduce the contaminant loadings in their discharges. Metro is currently evaluating removal of the contaminated sediments from the Denny Way CSO to prevent them from being flushed into Elliott Bay. In addition, improvements in the stormwater routing program to enhance in-line storage, and a notification and control system to reduce source toxicant discharges when overflows occur are under consideration (Romberg et al. 1987). Projected stormwater separation measures are anticipated to reduce the number of CSO events from 50 events/yr to approximately 10 events/yr by the mid-1990s (Romberg and Sumeri 1988).

In addition to the industrial laundries, an electroplating business in the basin discharges approximately 3,000 gal/day under a Metro industrial waste permit (Romberg et al. 1987). Plating baths used in the electroplating industry contain many metals, including silver. Both the industrial laundries and the electroplating facility are potential sources of metals and organic compounds in the basin.

5.2.2 Problem Station EW-05

Station EW-05 was located in the center of the East Waterway between Terminal 25 and Terminal 30, abreast of the approximate midpoint of Harbor Island (see Figure 4-14). This station scored higher in both biological (82 percent) and sediment chemistry (75 percent) contamination than any other East Waterway stations sampled in the receiving environment survey (PTI and Tetra Tech 1988).

Cadmium (13.4 mg/kg), mercury (E3.56 mg/kg), PCBs (E2,600 ug/kg), butyl benzyl phthalate (E1,100 ug/kg), p,p'-DDT (E100 ug/kg), p,p'-DDE (E37 ug/kg), and 1-methylphenanthrene (E830 ug/kg) exceeded HAET concentrations at Station EW-05. Lead (431 mg/kg) and zinc (559 mg/kg) exceeded LAET concentrations, and chlordane (E200 ug/kg), retene (E1,500 ug/kg), silver (E4 mg/kg) and di-n-octyl phthalate (E270 ug/kg) exceeded 90th percentile concentrations (PTI and Tetra Tech 1988).

Station EW-03, located approximately 1,100 ft upstream of EW-05 in the center of the East Waterway, did not exceed the AET or 90th percentile concentration for any contaminants (PTI and Tetra Tech 1988). Station EW-04, located approximately 650 ft upstream of EW-05, but closer to the western edge of the waterway, contained sediments with HPAH (E33,950 ug/kg) at concentrations exceeding HAET, as well as PCBs (E430 ug/kg) and mercury (0.486 mg/kg) at concentrations that exceeded LAET.

The two closest downstream stations, EW-07 and EW-08, were both approximately 800 ft away from Station EW-05. At each of these two stations, butyl benzyl phthalate (1,800 ug/kg at both Station EW-07 and EW-08) was the only chemical to exceed HAET concentrations. Of all the stations in the area, including historical stations in the main waterway and EW-06, which was located in the slip north of Terminal 25, no station had more than two chemicals that exceeded HAET (PTI and Tetra Tech 1988). Station EW-05 had seven chemicals at concentrations higher than HAET. It appears that Station EW-05 was a relatively isolated contaminated area in the receiving environment.

The Hanford CSO (W032) and the SW Hanford CSO/SD (162) are south of and relatively close to Station EW-05. The Hanford CSO (W032) discharges in the immediate vicinity of Station EW-05 (see Figure 4-14) and is a potential source of contaminants to this station. The Hanford CSO sediment contained five chemicals that exceeded HAET (see Table 4-1), including mercury (E4.99 mg/kg) and butyl benzyl phthalate (2,500 ug/kg). The SW Hanford CSO/SD sediment contained eight chemicals that exceeded HAET concentrations

(see Table 4-1), including PCBs at the highest concentration observed in the source study (185,000 ug/kg), and 1-methylphenanthrene (E480 ug/kg).

The relative distribution of metals in the Hanford CSO (W032) and the EW-05 sediments was similar except for the higher percentage of chromium (approximately 50 percent) in the Hanford CSO (W032) sample (Figure 5-21). Comparisons between these two sediments samples for the PAH compounds are difficult because of the large number of undetected compounds with relatively high detection limits (120-780 ug/kg) in both samples (Figure 5-22). Phenanthrene was the major LPAH contaminant (>55 percent) in both sediment samples, but the Hanford CSO (W032) sediment contained a relatively large amount of naphthalene (45 percent) and no anthracene, whereas the Station EW-05 sediment contained anthracene (29 percent) and no phenanthrene. The HPAH distribution was similar in the two sediment samples, except for benzo(a)pyrene and the total benzofluoranthenes, which were undetected in the Hanford CSO (W032) sediment at elevated detection limits (130-194 ug/kg). None of the elevated detection limits discussed above exceed HAET.

Comparisons between sediments from Station EW-05 and the other nearby drain, SW Hanford CSO/SD (162), are also presented in Figures 5-21 and 5-22. Aside from the large amount (89 percent) of copper (43,200 mg/kg) in the SW Hanford CSO/SD (162) sediments (the highest copper concentration observed in the source study), the relative distribution of metals in the two sediments was similar, especially the ratios of lead to mercury to silver to zinc (see Figure 5-21). The relative distributions of LPAH compounds (see Figure 5-22) were dissimilar because of the undetected compounds in the Station EW-05 sediments. The HPAH distributions matched relatively well and were comprised mainly of fluoranthene (25 percent vs. 20 percent), pyrene (25 percent vs. 18 percent), and chrysene (20 percent vs. 15 percent).

The Hanford CSO (W032) and the SW Hanford CSO/SD (112) were likely contributors to the sediment contamination at Station EW-05 based on their proximity to Station EW-05, the similarity in problem chemicals, and to a lesser extent, the similarity in the relative distribution of contaminants in the sediments.

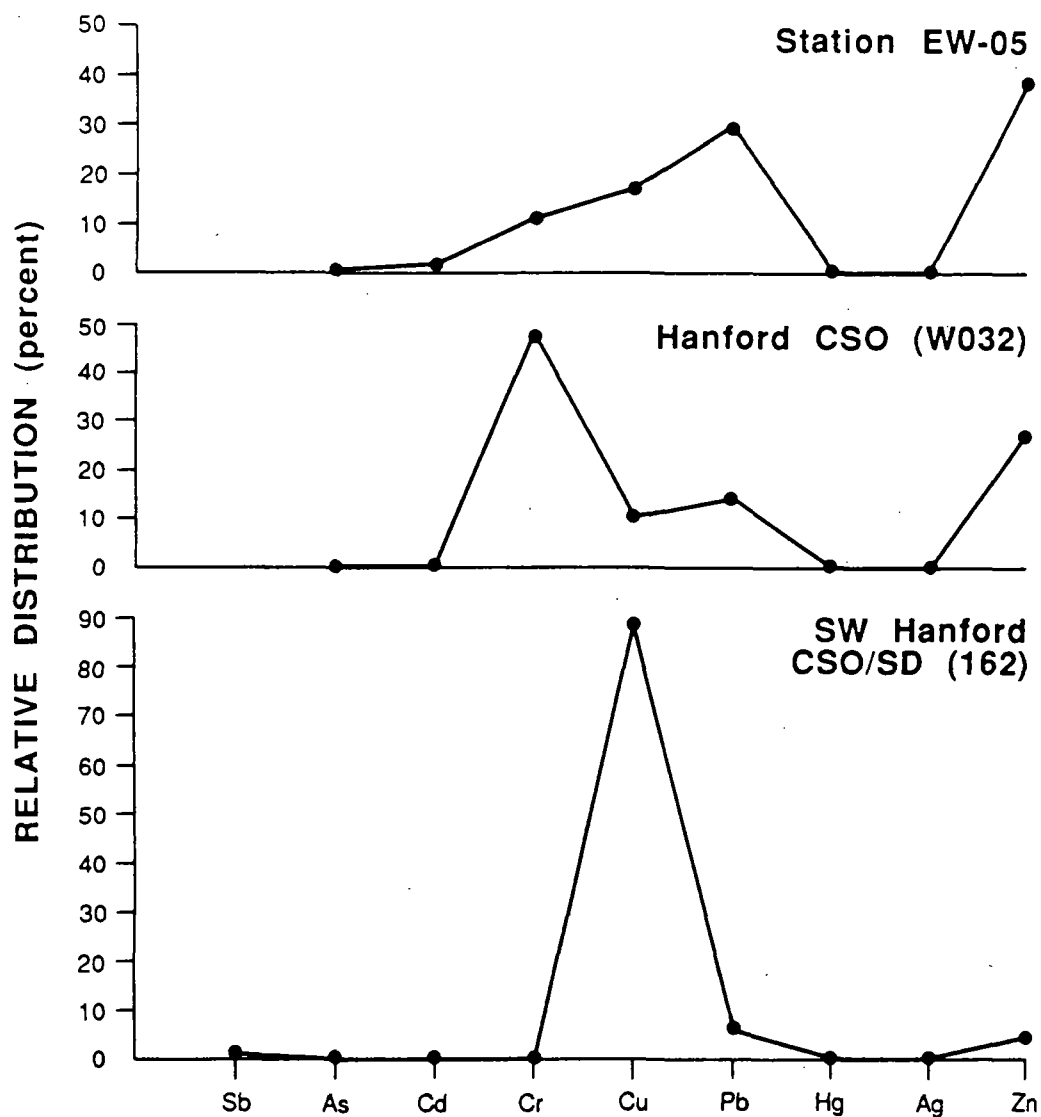


Figure 5-21. Comparison of relative percent distribution of metals in sediment from Station EW-05 and sediments from nearby drains.

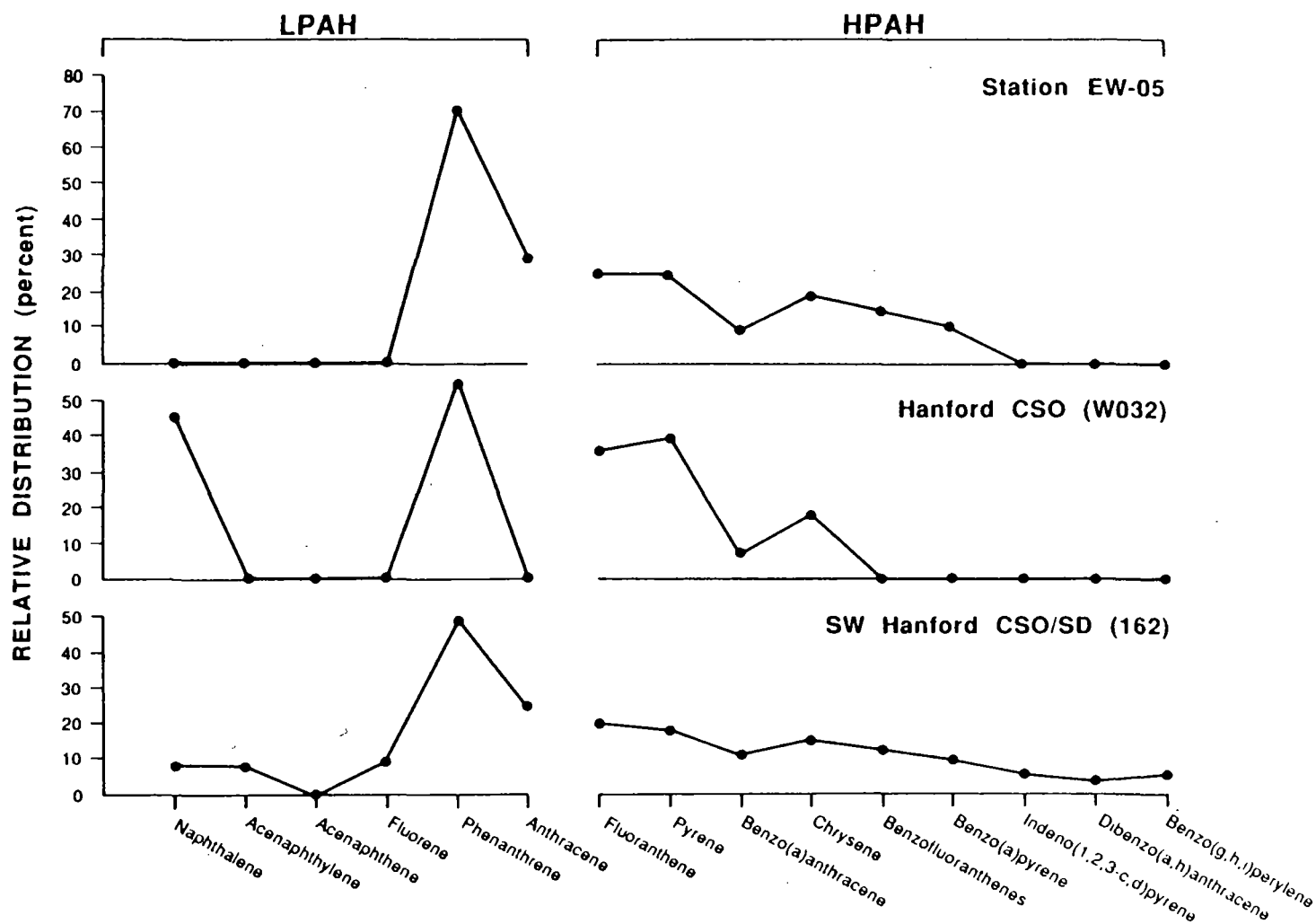


Figure 5-22. Comparison of relative percent distribution of LPAH and HPAH compounds in sediment from Station EW-05 and sediments from nearby drains.

Potential contaminant sources that were identified in the Hanford CSO (W032) and SW Hanford CSO/SD (162) basins are described in Section 4.3. Average annual discharge from the Hanford CSO (W032) (270 Mgal/yr) is greater than 4 times the annual flow in the SW Hanford CSO (W032) (60 Mgal/yr). The Hanford CSO (W032) appeared to be the major source of the two metals that were elevated at Station EW-05 (cadmium=13.4 mg/kg and mercury=3.56 mg/kg). The sediment from the Hanford CSO contained 6.27 mg/kg of cadmium and 4.99 mg/kg of mercury. Although cadmium (6.78 mg/kg) and mercury (1.97 mg/kg) were both present in the SW Hanford CSO/SD, the concentrations of these two metals were not elevated in Station EW-04 immediately offshore of the CSO/SD. Concentrations of cadmium and mercury at Station EW-04 (see Figure 4-14) were 1.07 mg/kg and 0.49 mg/kg, respectively. With the exception of cadmium, metals concentrations at Station EW-05 were consistently higher than concentrations at nearby stations. The highest concentration of cadmium (18 mg/kg) in the offshore stations near Station EW-05 occurred at historical Station 10039 (Malins et al. 1980, 1982).

The Lander CSO (W030) is another potential source of cadmium in this area. The concentration of cadmium in the sediment from the Lander CSO was 33.8 mg/kg. However, the station offshore of the Lander CSO (Station EW-09) did not exhibit an elevated cadmium concentration (2.84 mg/kg).

It has been reported that the presence of cadmium correlated well with the presence of PCBs, based on the distributions of these two chemicals in the entire East Waterway study area (PTI and Tetra Tech 1988). However, the distributions of these two contaminants in the area around Station EW-05 were somewhat dissimilar. Cadmium concentrations were highest at two stations along the centerline of the East Waterway (Station EW-05=13.4 mg/kg, Station 10039=18 mg/kg; see Figure 4-14). Cadmium concentrations decreased substantially at other nearby stations on either side of the waterway. The concentration of cadmium at Stations EW-04, EW-07, EW-06, A062, B062, and C062 ranged from 1.1 to 2.6 mg/kg. PCB concentrations in this same area were elevated (E2,143-E3,208 ug/kg) at both centerline stations (EW-05) and stations on the east side of the waterway (A062 and B062). Concentrations of PCBs at Stations EW-04 and EW-07 (E430 and E370 ug/kg, respectively) on

the west side of the waterway near Station EW-05 were generally low. These differences suggest that there may have been one or more different sources of cadmium and PCBs in the area around Station EW-05. Concentrations of PCBs were not elevated in the drains discharging into the east side of the waterway (E107-U480 ug/kg). The primary source of PCBs appeared to be the drains on the west side of the waterway. PCBs in the drain sediments exceeded the LAET in the SW Florida SD (E1,400 ug/kg) and the SW Lander SD (E1,300 ug/kg). PCBs exceeded the HAET in the sediment from the SW Hanford CSO/SD (E28,000-E341,500 ug/kg).

Sources of the PCBs in the drains on Harbor Island that have been identified include a metal recycler in the SW Hanford CSO/SD basin that handled PCB transformers (Ryan, C., 6 July 1987, personal communication) and an oil recycling company, which reportedly discharged waste oils at several locations around Harbor Island (Sweet-Edwards & Associates and Harper-Owes 1985). Both of these potential PCB sources are included on Ecology's list of hazardous waste sites (WEC Alert! 1987). In addition, the Port of Seattle found PCB contamination (2,000-4,000 ug/kg) in the sediments that were removed as part of the Terminal 18/20 redevelopment on Harbor Island (Port of Seattle, no date). The apparent discrepancy between the distribution of PCBs in the offshore sediments and the location of documented sources requires further investigation.

The absence of LPAH data to use in determining spatial gradients hindered source identification activities. Spatial gradients for LPAH could not be evaluated in the offshore sediments because of the high detection limits (300-2,100 ug/kg) for LPAH. Available data indicate that PAH was elevated at isolated areas throughout most of the East Waterway (PTI and Tetra Tech 1988). Of the drains discharging into the East Waterway, PAH compounds were identified as problem chemicals only in the Hanford CSO (2-methylnaphthalene) and the SW Hanford CSO/SD (1-methylphenanthrene).

There are many potential sources of PAH in the East Waterway. Bulk petroleum storage facilities are located on either side of the waterway. Many of these facilities have installed wells to recover product lost through leaks (Ryan, C., 6 July 1987, personal communication). Chevron

operated a bulk fuel storage facility on the east side of the East Waterway from the 1930s through 1985 when the property was purchased by the Port of Seattle. The property is now the site of the Port's Terminal 30 container facility (see Figure 4-14). Chevron initiated a product recovery operation in 1983 (Hotchkiss, D., 22 December 1987, personal communication) that removed approximately 150,000 gal of product from wells in this area. Free product has not been observed in the monitoring wells located adjacent to the shoreline since 1986 (GeoEngineers 1987). In addition, during the redevelopment of this site, approximately 35 ft of clean fill was placed on the outer edge of the terminal to isolate the remaining contaminated soil from the waterway. GeoEngineers (1987) concluded that the recovery program has immobilized most of the product remaining in the subsoil. Free product has been observed in isolated areas near the existing recovery wells. Consequently, this site is no longer considered a source of contaminants to the East Waterway.

Phthalate contamination in the vicinity of Station EW-05 was similar to the PAH contamination, in that phthalate concentrations were elevated in a wide area in the East Waterway (PTI and Tetra Tech 1988). Butyl benzyl phthalate exceeded the HAET (470 ug/kg) at Stations EW-05, EW-07, EW-08, EW-09, and EW-11 in the East Waterway. Evaluation of contaminant levels for the other phthalates was hampered by detection limits that frequently exceeded the HAET (e.g., 160 ug/kg for dimethyl phthalate).

Uses of phthalates are presented in Appendix H. Potential sources of phthalates in the East Waterway include decomposing garbage, wastewater pumped from ship bilges, and discharges from drains. Phthalates were identified as problem chemicals in the SW Lander SD (dimethyl phthalate) and the Hanford CSO (W032) (butyl benzyl phthalate).

5.2.3 Problem Station AB-01

Station AB-01 was located on the southwestern shore of Elliott Bay, due west of the northwestern corner of Harbor Island (see Figure 4-34). This station was designated as a high priority because of its high score for sediment chemistry contamination (88 percent), which equalled the highest of

the north Harbor Island scores for chemistry. Station AB-01's score for biological indicators of contamination was relatively low (25 percent) (PTI and Tetra Tech 1988).

Acenaphthene (E1,200 ug/kg), anthracene (E2,700 ug/kg), total LPAH (E10,000 ug/kg), fluoranthene (E10,000 ug/kg), indeno(1,2,3-cd)pyrene (E2,400 ug/kg), and mercury (E28.8 mg/kg) were found in Station AB-01 sediment at concentrations exceeding HAET. Copper (440 mg/kg) and zinc (322 mg/kg) concentrations exceeded LAET. The mercury concentration was the highest found in the receiving environment survey, including historical stations (PTI and Tetra Tech 1988). The next two closest stations, NH-10 and AB-02 (see Figure 4-34) contained mercury at E0.031 mg/kg and E0236 mg/kg, respectively. Station NH-10 was located approximately 300 ft southeast of Station AB-01, and Station AB-02 was located approximately 1,200 ft northwest of Station AB-01 (see Figure 4-34). LPAH concentrations decreased from E10,000 ug/kg at Station AB-01, to E3,350 ug/kg at Station AB-02, and E317 ug/kg at Station NH-10 (PTI and Tetra Tech 1988).

No sources of contaminants have been documented near Station AB-01. Station AB-01 was located 250-300 ft northwest of the SW Fairmount SD and SW Fairmount CSO (078) outfalls (see Figure 4-34). Both of these drains serve primarily residential areas. The SW Fairmount SD serves approximately 180 ac in West Seattle (see Map 3 in Map Appendix). Average annual flow is estimated at less than 30 Mgal/yr. The SW Fairmount CSO serves 281.5 ac. Prior to 1980, annual discharge from this overflow was estimated at 0.4 Mgal/yr. Overflows from the SW Fairmount CSO were reduced to 1/yr or less with implementation of the City of Seattle's 1980 CSO control plan (Corson, C., 6 May 1988, personal communication).

Because there was only a single offshore station in this area, it is not possible to determine contaminant gradients. Therefore, it is not known if contamination at Station AB-01 was caused by waterfront activities or spills from ships and recreational boats in the area. Ecology, U.S. EPA, and Metro have not identified any potential sources of contaminants in the storm drain basin or the CSO service area. The waterfront area north of Fairmount Ave. SW is currently undeveloped and part of the Alki Beach Park.

Contamination may be caused by historical land-use activities. At one time, there was a railroad siding, ferry terminal, marina, flour mill, and railroad trestle crossing to Seattle along the waterfront in this area (Dorpat 1986). There was also a drydock located on the shoreline north of this area. However, it was more than 1,000 ft north of Station AB-01 and likely did not affect the contaminant levels at Station AB-01. Many of these shoreline facilities had ceased operations by the 1920s (Dorpat 1986).

Mercury contamination at Station AB-01 may have been caused by spills or materials discharged from boats. Copper and zinc, which were the primary metal components in the sediment from Station AB-01, have been associated with shipyards and other shipping activities in Puget Sound (Tetra Tech 1986a).

PAH compounds are associated with fossil fuels. The ratio of methyl phenanthrene (MP) to phenanthrene (P) can be used as an indicator of the type of fuel source (i.e., combustion- or noncombustion-related; Prahl and Carpenter 1983). In general, phenanthrene is relatively more abundant in combustion fuel mixtures. The ratio measured in Station AB-01 ($MP/P=0.08$) suggests the PAH contamination in the sediments may have been related to combustion sources rather than petroleum sources.

5.2.4 Problem Station KG-01

Station KG-01 was located in Slip 1, which is east of the southeastern tip of Kellogg Island (see Figure 4-21). This station was designated as a high-priority station based primarily on its sediment chemistry contamination (75 percent), which was the highest of all the Kellogg Island stations. Station KG-01 also scored high for biological indicators of contamination (62 percent) (PTI and Tetra Tech 1988). Although no chemicals exceeded the HAET concentrations at this station, zinc (956 mg/kg), mercury (E0.478 mg/kg), HPAH (E14,770 ug/kg), and butyl benzyl phthalate (E88 ug/kg) exceeded LAET concentrations. Cadmium (5.19 mg/kg) and di-n-octyl phthalate (E250 ug/kg) exceeded 90th percentile concentrations but no AETs (PTI and Tetra Tech 1988).

The only nearby drain, the Brandon CSO (W041), is approximately 1,000 ft south of Station KG-01 (see Figure 4-21). The sediments analyzed from this CSO showed eight problem chemicals, including zinc (E1,900 mg/kg), mercury (E3.16 mg/kg), and an alkylated PAH, 2-methylnaphthalene (1,400 ug/kg), at concentrations that exceeded HAET (see Table 4-1). The relative distributions of metals in the sediments from the Brandon CSO and Station KG-01 were very similar (Figure 5-23). In both sediments, zinc was the most abundant metal, followed by lead, copper, and chromium. There are a limited number of data points to compare relative distributions of PAH in the two sediments (Figure 5-24) because of the number of PAH compounds undetected at elevated detection limits (180-1,800 ug/kg) in the sediment from the Brandon CSO. (None of these elevated detection limits exceed HAET concentrations.) However, in both sediments, phenanthrene (48 percent vs. 87 percent) and anthracene (29 percent vs. 13 percent) were the two major LPAH constituents, and fluoranthene (24 percent vs. 42 percent) and pyrene (23 percent vs. 37 percent) were the two largest HPAH constituents. Given the similarity of problem chemicals and distribution of chemicals in the sediments, it is possible that the Brandon CSO (W041) contributed to the sediment contamination at Station KG-01, despite the physical distance between the two areas.

The following potential sources of metals have been identified in the Brandon CSO service area: an abandoned landfill and three facilities permitted to discharge waste to the sanitary sewer under Metro's industrial pretreatment program (i.e., a metal plater, a tank cleaning service, and a manufacturer of aircraft equipment). However, the relative contribution of metals from each of these facilities is unknown (see Section 4.3).

Of the PAHs, only 2-methylnaphthalene was identified as a problem chemical in Brandon CSO sediments. The distribution of LPAH in the sediments (87 percent phenanthrene and 13 percent anthracene) and relatively low concentrations of LPAH (within the range of concentrations reported in urban street dust) suggest that the PAH contamination in the Brandon CSO was primarily caused by nonpoint sources such as urban runoff.

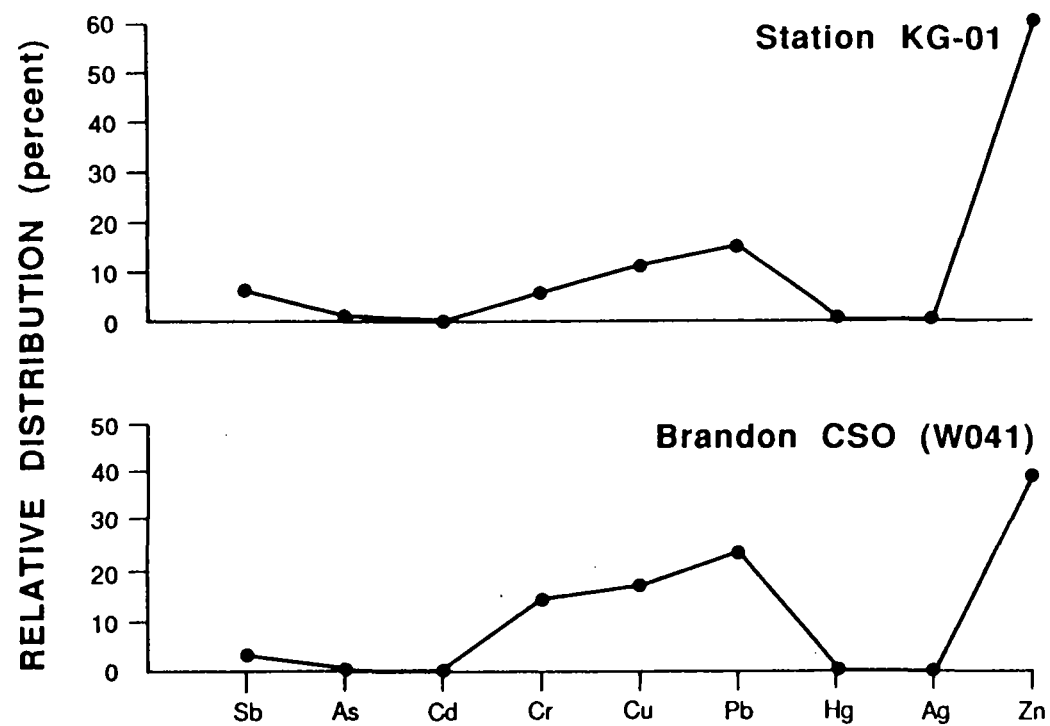


Figure 5-23. Comparison of relative percent distribution of metals in sediment from Station KG-01 and sediment from a nearby drain.

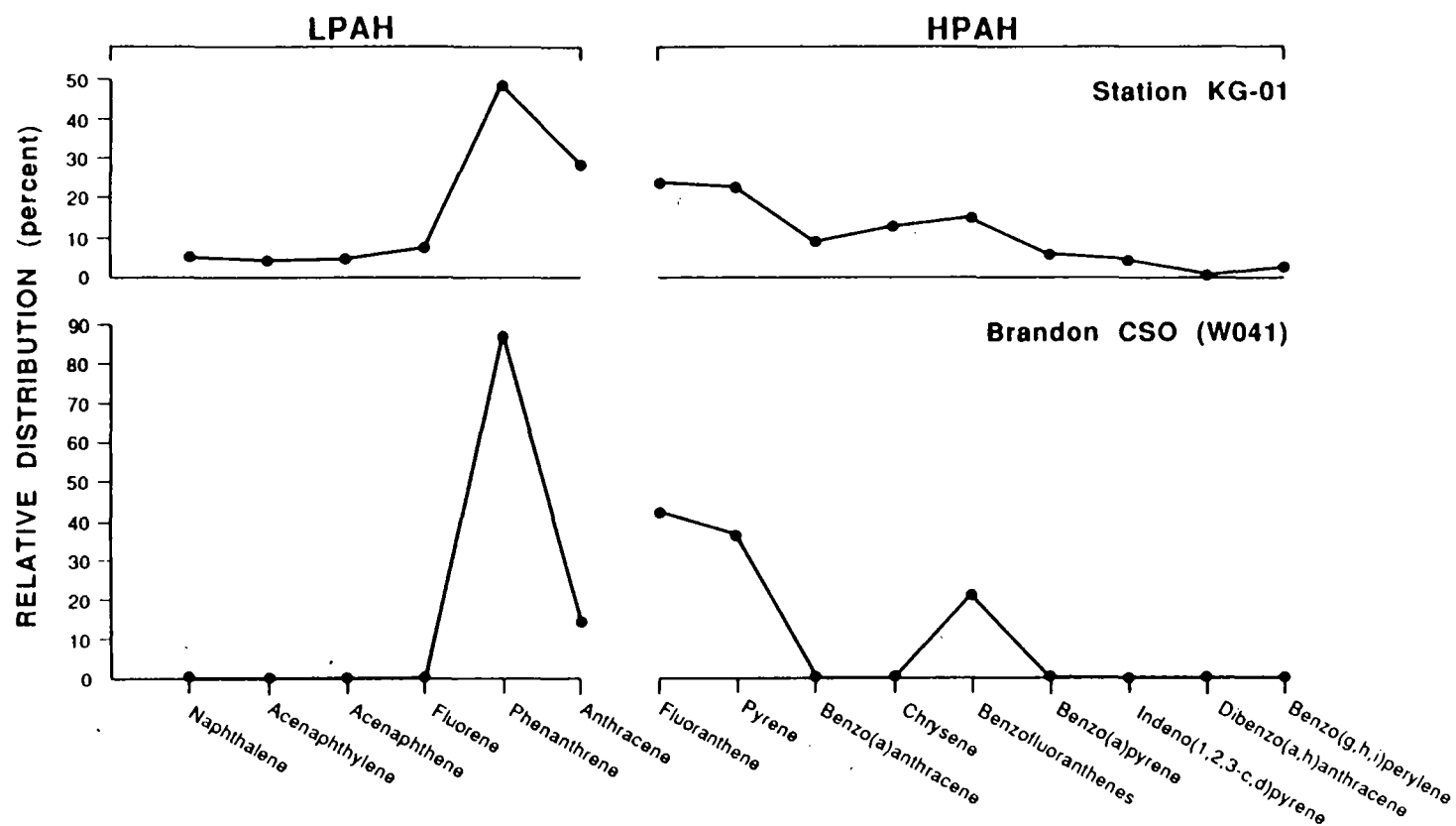


Figure 5-24. Comparison of relative percent distribution of LPAH and HPAH compounds in sediment from Station KG-01 and sediment from a nearby drain.

The Brandon CSO is one of the smaller Metro CSOs (35 Mgal/yr overflow volume). Therefore, it is uncertain whether this CSO constituted the major source of contamination at Station KG-01. Further investigation of potential sources in the immediate vicinity of Slip 1 is required to confirm contaminant contributions from other sources.

No sources have been documented in Slip 1. There are no Metro or city storm drains or CSOs that discharge directly into the slip. However, a U.S. EPA dive team inspected the shoreline around the slip and reported that there were eight pipes of unknown origin that discharge into Slip 1, ranging in diameter from 2 in to 12 in (Karna, D., 30 July 1985, personal communication). All of these pipes discharged into the north side of Slip 1. The property along the north shoreline of Slip 1 is currently occupied by a federal office building. The remainder of the area bordering Slip 1 is occupied by a marine construction company and a shipbuilder. None of these facilities are permitted to discharge wastes to the waterway. Further investigation is required to determine if these facilities are potential sources of the contamination found at Station KG-01.

5.2.5 Problem Stations KG-05 and KG-06

Stations KG-05 and KG-06 were located approximately 550 ft from each other in the Duwamish River north of Kellogg Island (see Figure 4-21). Both stations received identical scores for biological indicators of contamination (75 percent, the highest of all Kellogg Island stations) and for sediment chemistry indicators of contamination (62 percent) (PTI and Tetra Tech 1988). Because of these similar scores and their proximity, the two stations are discussed together here.

At Station KG-05, there were no chemicals that exceeded HAET concentrations, but lead (500 mg/kg), mercury (E1.63 mg/kg), zinc (354 mg/kg) and PCBs (E180 ug/kg) exceeded LAET concentrations, and cadmium (4.1 mg/kg) exceeded the 90th percentile concentrations. 2-Methylnaphthalene was undetected at a detection limit of 8,900 ug/kg, which exceeded the HAET by a factor of 13 (PTI and Tetra Tech 1988).

At Station KG-06, PCBs (E3,100 ug/kg), p,p'-DDT (E270 ug/kg), 2-methylnaphthalene (1,900 ug/kg), and butyl benzyl phthalate (E690 ug/kg) exceeded HAET concentrations. Mercury (E0.462 mg/kg) and zinc (453 mg/kg) were found at concentrations exceeding LAET, while arsenic (54.2 mg/kg) and retene (E1,700 ug/kg) exceeded 90th percentile concentrations at this station (PTI and Tetra Tech 1988).

Analysis of sediments from other nearby stations did not detect many chemicals exceeding AET values. At Station KG-04, which is less than 100 ft northeast (slightly downstream) of Station KG-05, only two chemicals, lead (E325 mg/kg) and zinc (E265 mg/kg), exceeded AET values, and both of those only slightly exceeded LAET concentrations (PTI and Tetra Tech 1988). Historical U.S. EPA Station 10, located less than 300 ft northeast (downstream) of Station KG-06, did not exhibit chemical concentrations exceeding any AET values (U.S. EPA 1982, 1983). Thus, Stations KG-05 and KG-06 appeared to be relatively isolated areas of contamination.

The two drains closest to Stations KG-05 and KG-06 are the Diagonal Way CS0/SD (111) and the Diagonal Ave. S. SD. The Diagonal Way CS0/SD sediments contained seven problem chemicals (see Table 4-1), none of which were metals. The chemicals did not match the problem chemicals found in Stations KG-05 or KG-06 sediments (see Table 4-1). The Diagonal Ave. S. SD sediments contained only two chemicals exceeding HAET (see Table 4-1), indeno(1,2,3-cd)pyrene, which is an HPAH compound, and total phthalates (6,237 ug/kg, all of which was di-n-octylphthalate). Neither of these chemicals were problem chemicals in Stations KG-05 or KG-06 sediments.

Relative distributions of metals (Figure 5-25) were similar between the KG-06 and Diagonal Way CS0/SD sediments (zinc=50 percent vs. 51 percent, lead=18 percent vs. 18 percent, and copper=15 percent vs. 14 percent), but relatively poor agreement for metals between all the other receiving environment sediment/drain sediment pairings.

With the exception of phenanthrene (E860 ug/kg), LPAH compounds were undetected in KG-06 sediments at elevated detection limits (190-670 ug/kg, none of which exceeded HAET), making it impossible to evaluate the relative

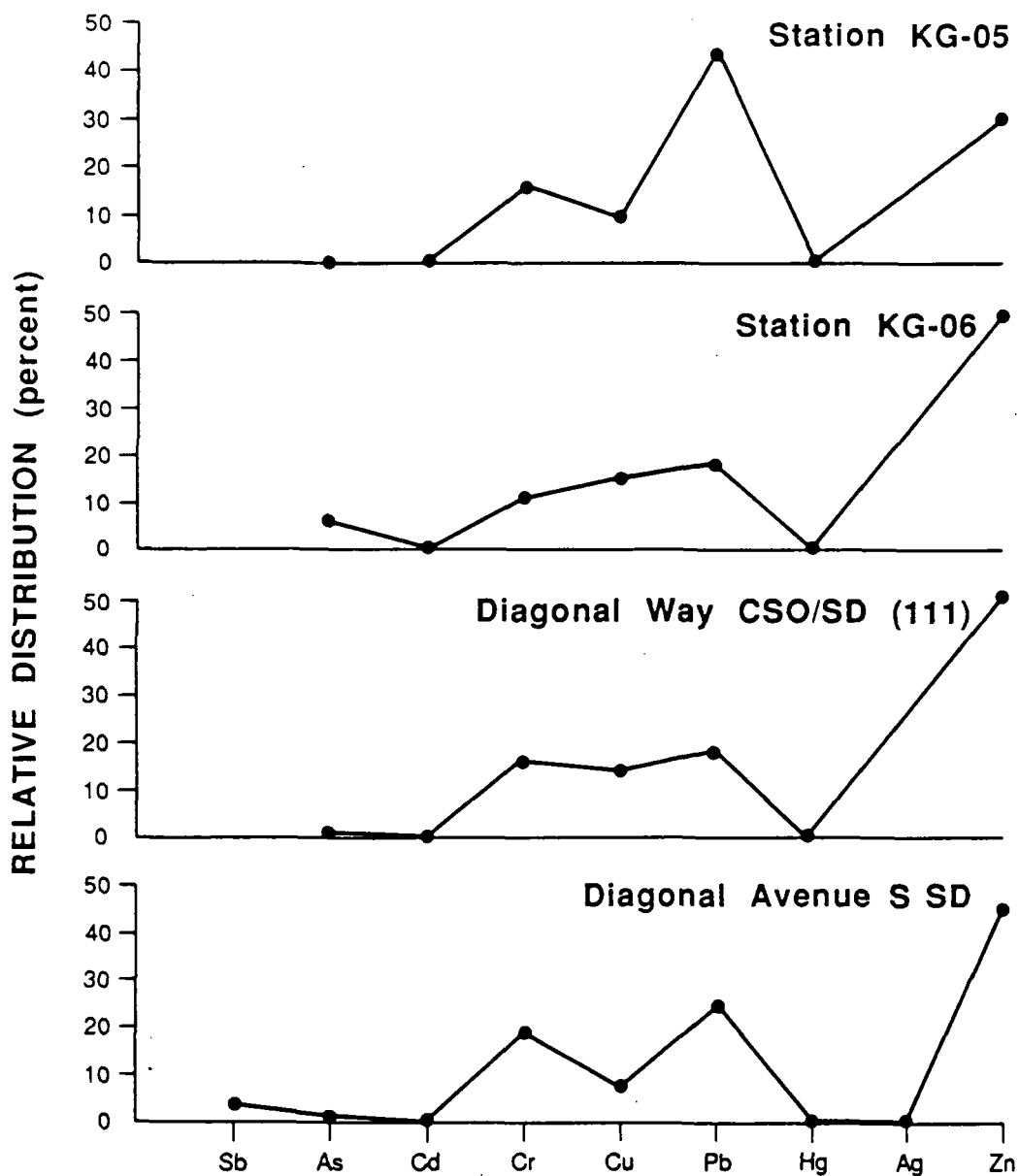


Figure 5-25. Comparison of relative percent distribution of metals in sediments from Stations KG-05 and KG-06 and sediments from nearby drains.

distribution of LPAH in this sample. For Station KG-05, LPAH compounds (except phenanthrene at E1,000 ug/kg) were also undetected, but at more elevated detection limits (1,700-5,900 ug/kg), thereby preventing evaluation of the relative distribution of LPAH. The LPAH detection limits for Station KG-05 sediments exceeded the HAET for each individual LPAH compound except anthracene.

The relative distribution of HPAH (Figure 5-26) in KG-06 sediments and the Diagonal Ave. S. SD was similar to a larger extent relative to those for the KG-06 sediment and the Diagonal Way CSO/SD. Evaluation of the HPAH distribution in Station KG-05 sediment is difficult because of the five compounds that were undetected at elevated detection limits (1,100-1,900 ug/kg). The detection limits for indeno(1,2,3-cd)pyrene (1,100 ug/kg) and dibenzo(a,h)anthracene (1,900 ug/kg) exceeded HAET for those two compounds.

Given the general dissimilarities in sediment chemistries between these two receiving environment stations and the two drains discussed, a link between the Diagonal Way CSO/SD (111) or the Diagonal Ave. S. SD and the sediment contamination at Station KG-05 or KG-06 could not be demonstrated, despite their proximity to each other.

In addition to the Diagonal Way CSO/SD (111) and Diagonal Ave. S. SD, two Metro CSOs (W034 and W035) discharge into the Duwamish River near Stations KG-05 and KG-06. These two CSOs function as emergency overflows for the siphon on Metro's interceptor line. Flow from the combined sewer system on the west side of the Duwamish River is transported under the river in the siphon, which connects to the Elliott Bay Interceptor on the east side of the river (see Figure 2-1). Discharges from the siphon overflows contain contributions from the entire West Seattle service area (see Map 2 in Map Appendix). Sediment samples were not collected from the siphon overflows during the source investigation. The average annual discharge from the east siphon overflow (W034) is estimated at 130 Mgal/yr (see Table 2-1). The west siphon CSO (W035) is not expected to overflow under average annual rainfall conditions. Because of the large area served by the siphon overflows, there are numerous potential contaminant sources in the

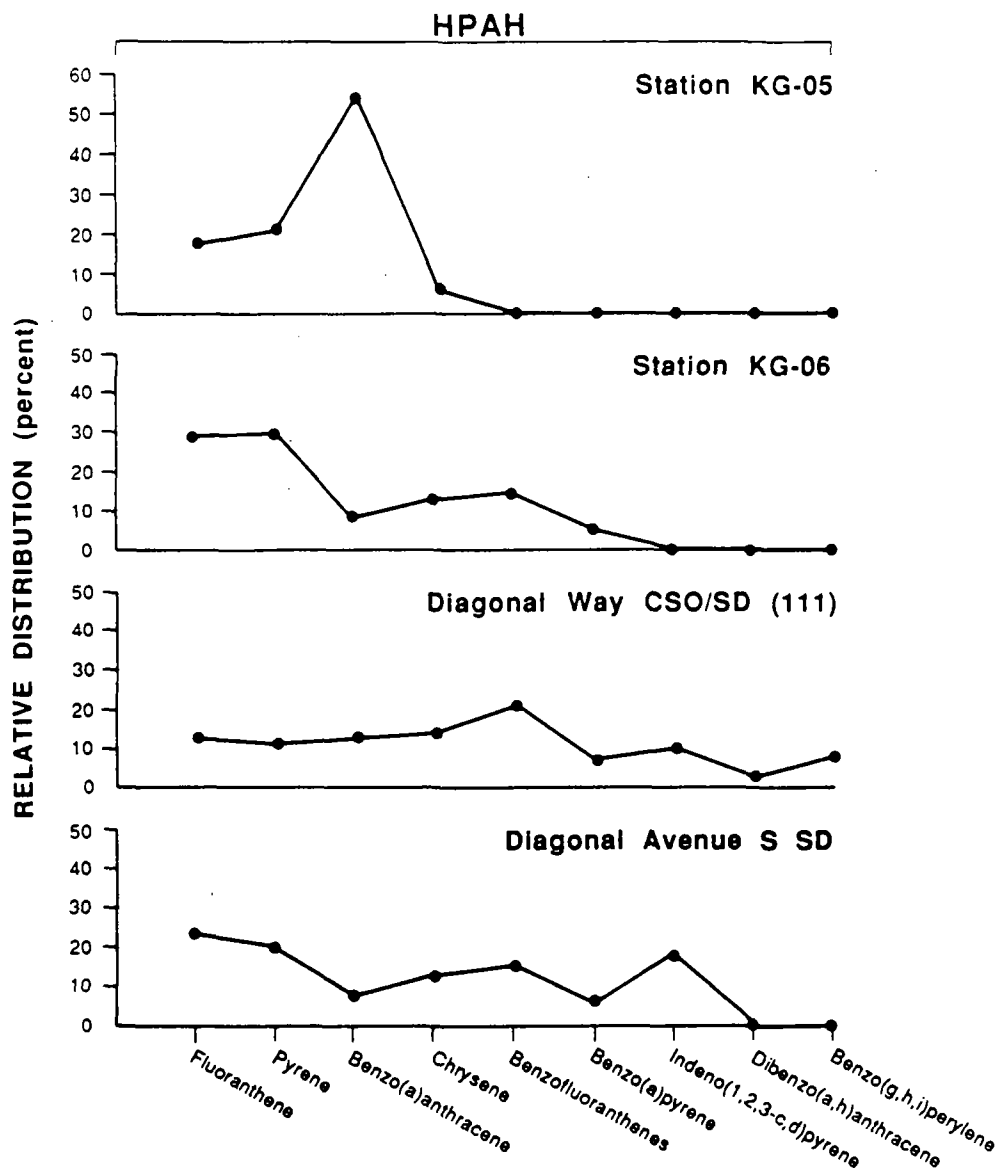


Figure 5-26. Comparison of relative percent distribution of HPAH compounds in sediments from Stations KG-05 and KG-06 and sediments from nearby drains.

area (see Map 4 in Map Appendix). The siphon serves all of Harbor Island and the industrial waterfront area along the west side of the Duwamish River. However, more information is needed to determine whether discharge from the siphon emergency overflows were the major source of contamination at Stations KG-05 and KG-06.

Station KG-06 was located adjacent to an area that was dredged by the Port of Seattle in 1967 and 1978 (see Figure G-6 in Appendix G). Approximately 9,700 yd³ of material were removed during the 1978 Port of Seattle dredging operations (see Figure G-6 in Appendix G). Resuspension and deposition of sediments during this dredging operation may have affected the sediments at Station KG-06.

Land-use activities along the waterfront area adjacent to Stations KG-05 and KG-06 may also have contributed to the sediment contamination at these two stations. The west side of the Duwamish River adjacent to Station KG-06 is currently occupied by a lumber company, a tug and barge operation, and Terminal 105. Prior to 1984, the lumber company had a NPDES permit to discharge noncontact cooling water into the Duwamish River. The permit was cancelled in 1984. No information is currently available on the tug and barge operation. They are not permitted to discharge wastes to the river, and are not included on Ecology or U.S. EPA's list of potential problem sites (see Appendix B).

In 1982, Terminal 105 was used as an upland disposal site for PCB-contaminated sediments removed from the east side of Harbor Island during the redevelopment of Terminal 18/20 (Port of Seattle, no date). Approximately 16,000 yd³ of material containing 2,000-4,000 ug/kg of PCBs were deposited in the confined upland disposal site at Terminal 105. The groundwater in the area of the disposal site was monitored by the Port of Seattle prior to disposal and for a 1-yr period after disposal operations were completed. PCBs were not detected in the groundwater samples collected after the disposal operations were completed (Port of Seattle, no date). The organic contaminants detected in the monitoring wells 4 mo after disposal operations were completed included: beta-BHC, delta-BHC, and dieldrin at concentrations of 1-2 ug/L. Heptachlor epoxide, dieldrin, and

p,p'-DDE at concentrations of 0.02-0.04 ug/L, and phthalates at concentrations less than 1 ug/L were detected in the groundwater 1 yr after disposal. In addition, phenols were detected at a maximum concentration of 27 ug/L in samples collected 2, 4, and 7 mo after disposal operations were completed (Port of Seattle, no date).

Further investigation is needed in this area to determine the source of contamination at Stations KG-05 and KG-06. Because both are located within the Duwamish River, it is possible that contaminated sediments are not associated with nearshore sources, but instead may be related to sediments transported from upstream and temporarily deposited at this location.

5.2.6 Problem Station DR-12

Station DR-12 was located in Slip 3 on the Duwamish River (see Figure 4-24). It had the highest score of all Duwamish River stations for chemical contamination (88 percent), and a score of 75 percent for biological indicators of contamination (PTI and Tetra Tech 1988). Sediments from Station DR-12 contained no chemicals at concentrations that exceeded HAET, but concentrations of arsenic (449 mg/kg), zinc (969 mg/kg), and copper (386 mg/kg) exceeded both LAET and 90th percentile concentrations. Lead (307 mg/kg), PCBs (E830 ug/kg), fluoranthene (E2,100 ug/kg), and indeno-(1,2,3-cd)pyrene (E630 ug/kg) all exceeded LAET concentrations (PTI and Tetra Tech 1988).

Sediments from the upstream drain, Fox S. CSO/SD (116), exhibited a large number of problem chemicals. This CSO/SD was sampled at three different points, MH1, MH2, and MH3 (see Section 3.2 and Figure 4-31). The sediments from MH3 contained a total of 32 problem chemicals, the largest number in the present study (see Table 4-1). Among those 32 chemicals were arsenic (1,760 mg/kg), zinc (E4,940 mg/kg), copper (1,420 mg/kg), lead (1,440 mg/kg), HPAH (E134,700 ug/kg), and LPAH (L39,486 ug/kg) at concentrations exceeding HAET. The LPAH and HPAH concentrations were the highest observed in any drain sediment, and several LPAH and HPAH compounds exceeded HAET concentrations. The sediment from MH2 contained four problem chemicals (see Table 4-1), including arsenic (1,050 mg/kg), zinc (E3,020 mg/kg), and

lead (894 mg/kg) at concentrations exceeding HAET. The sediment from MH1 contained 13 problem chemicals (see Table 4-1), including arsenic (893 mg/kg), zinc (E5,980 mg/kg), copper (2,290 mg/kg), lead (1,106 mg/kg), and LPAH (E8,800 ug/kg), each at concentrations that exceeded HAET.

The relative distributions of metals (Figure 5-27), and PAH (Figure 5-28) in the sediment from Station DR-12 were similar to those in the sediment from MH3 of the Fox S. CSO/SD. Additionally, the ratio of HPAH to LPAH in the MH3 sediment (77 percent HPAH, 23 percent LPAH) was virtually identical to that in Station DR-12 sediment (76 percent HPAH, 24 percent LPAH). Based on proximity and the close similarity in sediment chemistries and problem chemicals (especially metals), it is likely that the Fox S. CSO/SD (116) contributed to the sediment contamination at Station DR-12.

Sediment contamination at Station DR-12 is probably associated with operations at the Marine Power and Equipment shipyard, located along the entire south shoreline of Slip 3. The shipyard operates a shipbuilding and ship repair facility, with drydocks and synchrolift facilities located near the mouth of Slip 3. As explained in Section 4.3, metals found offshore of the facility (i.e., arsenic, copper, and zinc) are associated with sandblasting activities at the shipyard. Metals contamination in the sediments could have resulted both from direct discharge of sandblast grit from the drydock and synchrolift, and from stormwater runoff from the property and surrounding area that was exposed to fugitive dust emissions.

In the past, spent sandblast material was released to the waterways when drydocks were flooded. In addition, fugitive dust emissions from upland sandblasting activities probably entered the waterways via stormwater runoff from the surrounding area. Under the current NPDES-permit requirements, best management practices must be implemented to control the release of sandblast materials from shipyard operations. Contaminants measured in the sediments collected from storm drain catch basins on the shipyard property were similar to the contaminants found in offshore sediments (see Section 4.3). U.S. EPA divers also reported that spent sandblast grit was

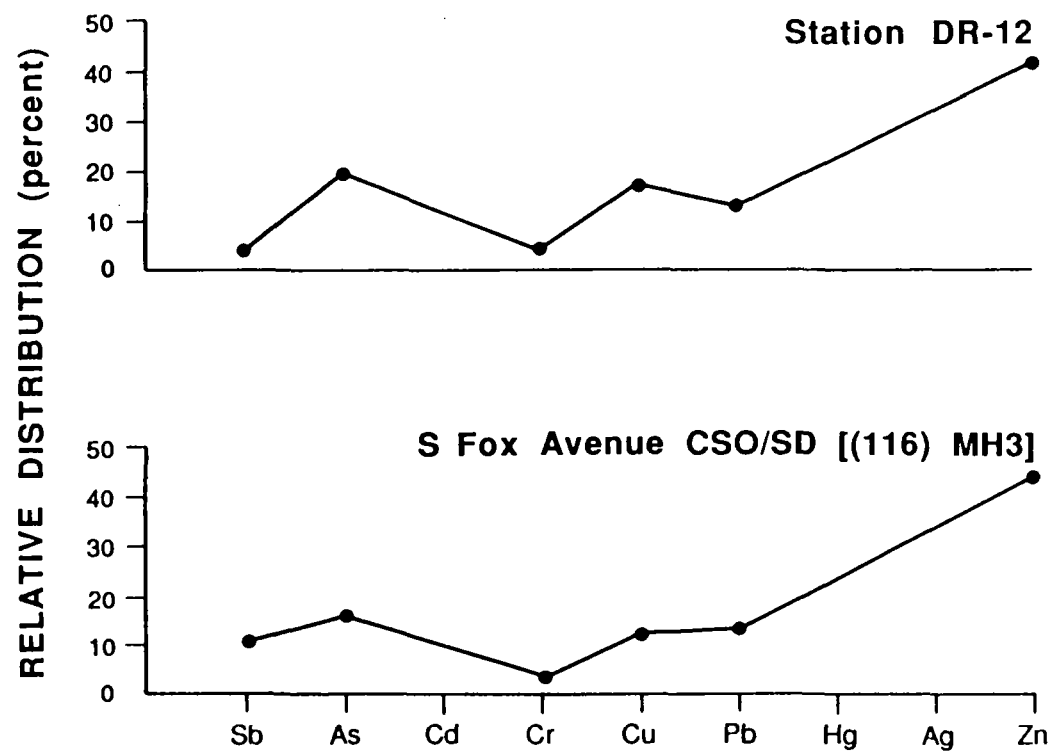


Figure 5-27. Comparison of relative percent distribution of metals in sediment from Station DR-12 and sediment from a nearby drain.

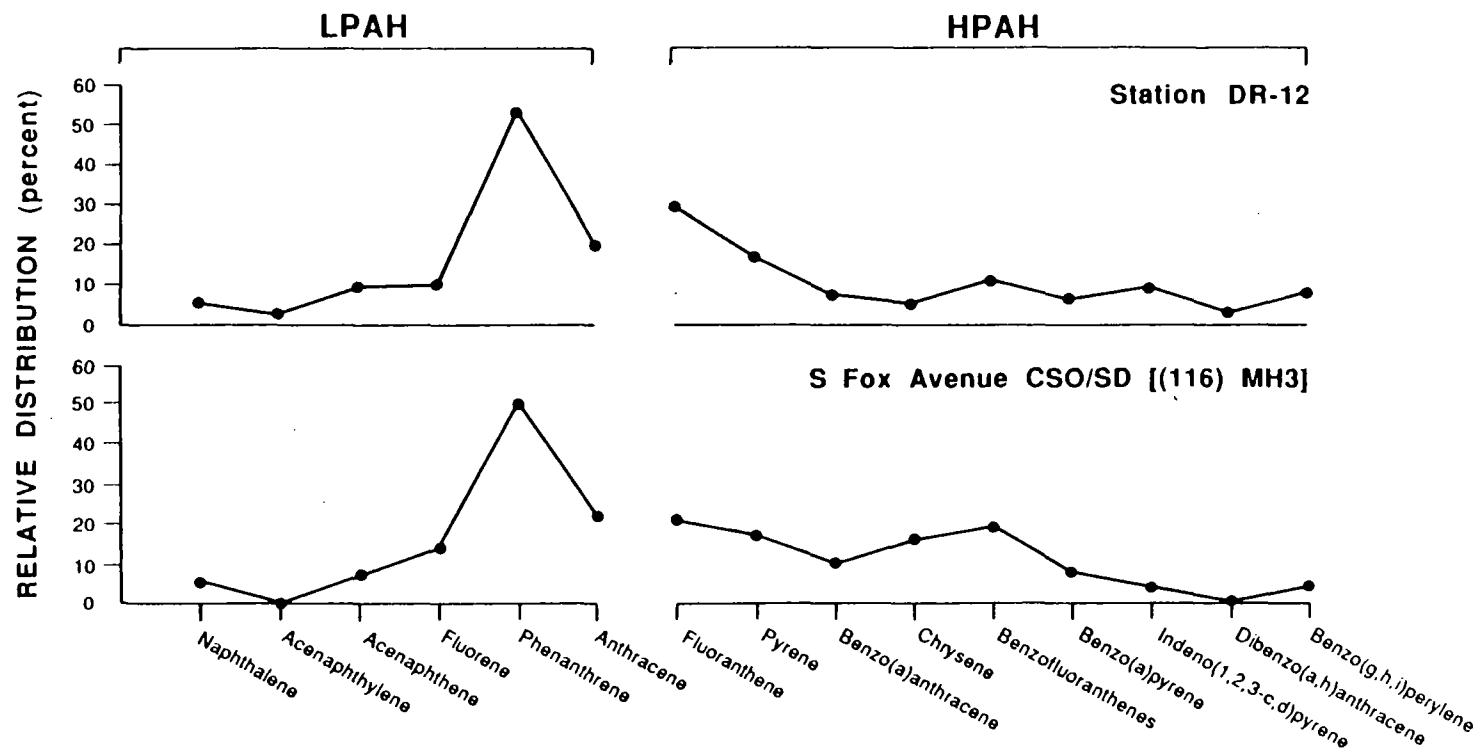


Figure 5-28. Comparison of relative percent distribution of LPAH and HPAH compounds in sediment from Station DR-12 and sediment from a nearby drain.

present in the sediments beneath the synchrolift structure (Karna, D., 14 April, 1988, personal communication).

Sandblast grit frequently contains high concentrations of metals. It has been reported that, in the past, shipyards in the study area used slag from a copper smelter in British Columbia as sandblasting material (Dexter et al. 1981). The slag from this smelter, which is no longer in operation, contained high concentrations of copper (1,000 mg/kg). Complete chemical analyses of the British Columbia smelter slag are not available. In addition to the contaminants present in the slag itself, spent sandblast grit also contains contaminants from the materials (primarily paint chips) removed from the ship's hull. Lead and zinc are added to marine paints to inhibit corrosion. Copper, organotin, and in the past, mercury, were added to prevent biofouling (Muehling 1987).

Marine Power and Equipment is currently under a Consent Decree that requires the implementation of best management practices and prohibits the discharge of pollutants into the waterway, unless authorized under an NPDES permit (Ecology, no date). In addition, the company is required to dredge Slip 3 and the Duwamish River offshore of their facility to remove the contaminated sediments (Parkins, R., 15 March 1988, personal communication).

No other property owners along the waterfront in Slip 3 have been identified as potential sources contributing to the metals contamination in the offshore sediments. The area along the north shoreline and the head of Slip 3 is currently occupied by a cold storage warehouse, a marine equipment supplier, and two other warehouses. None of these facilities are permitted to discharge wastes into the waterways.

5.2.7 Problem Station DR-15

Station DR-15 was located in Slip 2 of the Duwamish River (see Figure 4-24). It was designated as a problem station because of its maximum possible score (100 percent) for biological indicators of contamination. The score for chemical contamination at this station was 50 percent (PTI and Tetra Tech 1988). In the sediment from Station DR-15, di-n-octyl phthalate

(E310 ug/kg) exceeded the 90th percentile concentration, and PCBs (E230 ug/kg) exceeded the LAET concentration (PTI and Tetra Tech 1988).

The closest upstream drain, the Michigan CSO (W039), had the second highest number of problem chemicals (19) in the source study (see Table 4-1). These 19 chemicals included PCBs (E35,388 ug/kg), butyl benzyl phthalate (E3,300 ug/kg), and total phthalates (E4,222 ug/kg) at concentrations exceeding HAET. Total phthalates (L3,623 ug/kg) also exceeded HAET concentrations in the sediment from the Michigan SD, which is located due west (across the Duwamish River) of the Michigan CSO (W039). Both sources are approximately the same distance south of Station DR-15.

The relative distribution of metals in the sediment from the Michigan CSO (W039) and Michigan SD did not match the relative distribution of metals in the sediment from Station DR-15 (Figure 5-29). The relative abundance of lead was higher in each of the drains, and the relative abundance of zinc was lower compared to Station DR-15. However, the relative distribution of LPAH and HPAH in both the Michigan CSO (W039) and the Michigan SD sediments was similar to a larger extent to the relative distribution of LPAH and HPAH in Station DR-15 sediments (Figure 5-30).

Given the proximity of the two drains, the similarity in problem chemicals for each sediment, and to a lesser extent the distribution of chemicals within each sediment, it is possible that both the Michigan CSO (W039) and the Michigan SD contributed to the contamination of the sediment at Station DR-15.

Station DR-15 is located on the edge of an area that was dredged by Kaiser Cement in 1979 (see Figure G-7 in Appendix G). Approximately 7,500 yd³ of material were removed. The sediments at Station DR-15 were probably disturbed during the dredging operations. Therefore, the contaminants (di-n-octyl phthalate and PCBs) may be related to historical rather than recent activities in the area.

There are no documented sources of contamination near Station DR-15. No storm drains or CSOs discharge directly into Slip 2 (see Figure 1-2). The

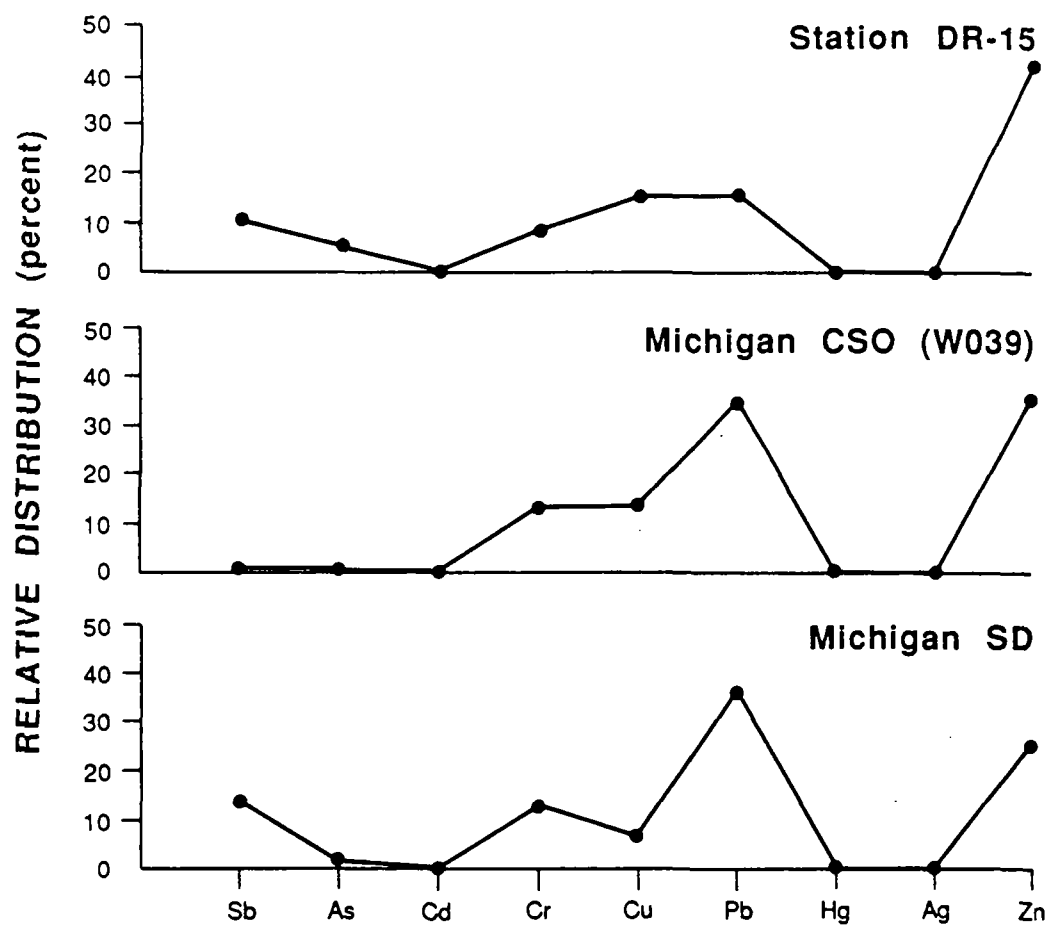


Figure 5-29. Comparison of relative percent distribution of metals in sediment from Station DR-15 and sediment from nearby drains.

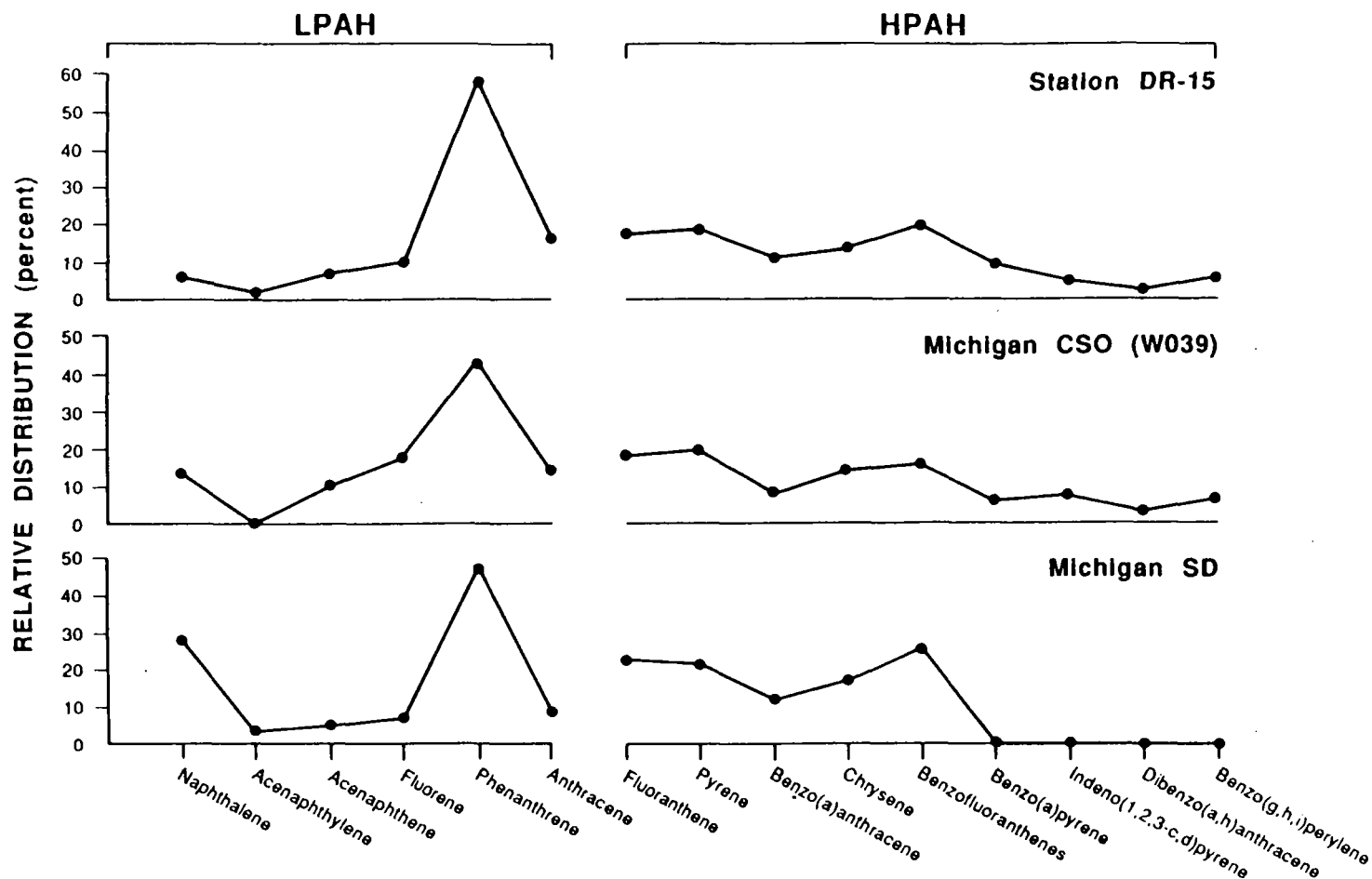


Figure 5-30. Comparison of relative percent distribution of LPAH and HPAH compounds in sediment from Station DR-15 and sediments from nearby drains.

Michigan CSO (W039), which is located approximately 800 ft upstream of the slip on the west side of the Duwamish River, is the nearest documented discharge. Numerous potential sources have been identified in the Michigan CSO service area (see Table 4-14 and Map 4 in Map Appendix). The Michigan CSO is one of the larger Metro CSOs in the project area. Average annual discharge from this CSO, estimated at 250 Mgal/yr, accounts for about 13 percent of the total Metro CSO volume in the study area. Because of riverine transport processes, it is not known to what extent the CSO affects sediment contaminant levels at the head of Slip 2. Average annual flow in the Duwamish River (measured upstream of the project area, near Auburn) is reported at 320,000 Mgal/yr (McGarock et al. 1986), and the effects of the CSO may be masked due to dilution by the river.

Limited data are available to establish contaminant gradients to link contamination in Slip 2 with the Michigan CSO. U.S. EPA historical Stations E13, E13A, and E14 were analyzed for PCBs, but not phthalates. PCB concentrations were relatively constant in Slip 2 (140-230 ug/kg). However, Stations DR-13 and DR-14, which were located in the Duwamish River upstream of Slip 2, exhibited greater concentrations of PCBs (i.e., E950 and E810 ug/kg, respectively). The maximum PCB concentration in the area upstream of Slip 2 occurred at Station DR-10 (E2,100 ug/kg). This difference suggests that PCB contamination may have been related to upstream sources. PCB-contaminated sediments may have been transported downstream and deposited in the relatively quiescent area of Slip 2. Phthalate concentrations at upstream stations were generally less than the concentration at Station DR-15 (E310 ug/kg di-n-octyl phthalate). Di-n-octyl phthalate concentrations at Stations DR-10, DR-13, and DR-14 (B1.3 ug/kg, E81 ug/kg, and B1.1 ug/kg, respectively) indicated that phthalate contamination was not caused by upstream sources. Further investigation is required to determine if the Michigan CSO was the major source of contamination in Slip 2.

The Michigan SD, located across the Duwamish River and about 300 ft south of Slip 2, may not have been a major source of the contamination observed in Slip 2. Average annual discharge from the Michigan SD is estimated at only 80 Mgal/yr. Although the contaminants in the drain sediment, particularly di-n-octyl phthalate, were similar to the contaminants

found at Station DR-15, the station immediately offshore of the Michigan SD (DR-14) did not contain elevated concentrations of di-n-octyl phthalate (B1.1 ug/kg).

Phthalate contamination at Station DR-15 may have been caused by a source in the immediate vicinity, such as shoreline discharges or direct discharges from ships entering Slip 2. The shoreline surrounding Slip 2 is currently occupied by a concrete batch plant and a gypsum product manufacturer.

5.2.8 Problem Station DR-16

Station DR-16 was located north of Terminal 115 on the western side of the Duwamish River (see Figure 4-24). It was designated as a problem station because of its score for biological indicators of contamination (100 percent). The station tied with Station DR-15 as the highest of all the Duwamish River station scores. The station's score for chemical contamination was 62 percent (PTI and Tetra Tech 1988). The sediment from Station DR-16 contained indeno(1,2,3-cd)pyrene, an HPAH compound, at a concentration (E940 ug/kg) that exceeded HAET. Butyl benzyl phthalate (E92 ug/kg), PCBs (E680 ug/kg), zinc (E429 mg/kg), LPAH (E6,000 ug/kg), and HPAH (E17,000 ug/kg), as well as several individual LPAH and HPAH compounds, all exceeded LAET concentrations. LPAH and HPAH concentrations were 4-7 times higher at Station DR-16 than at Station DR-17, the next downstream station (PTI and Tetra Tech 1988). Station DR-16 was located less than 100 ft from the SW Graham SD outfall. Sediments from this SD contained no chemicals that exceeded HAET or 90th percentile concentrations.

The relative distribution of metals in the sediment from Station DR-16 (Figure 5-31) matched the relative distribution of metals in the SW Graham SD sediment, except for the greater abundance of lead (30 percent vs. 15 percent) in the drain sediment. PAH relative distributions were not compared, because PAH compounds were generally undetected in the drain sediment at reasonable detection limits (i.e., <20 ug/kg). Based primarily on the complete lack of problem chemicals in the storm drain, it could not be demonstrated that the SW Graham SD was contributing to the sediment

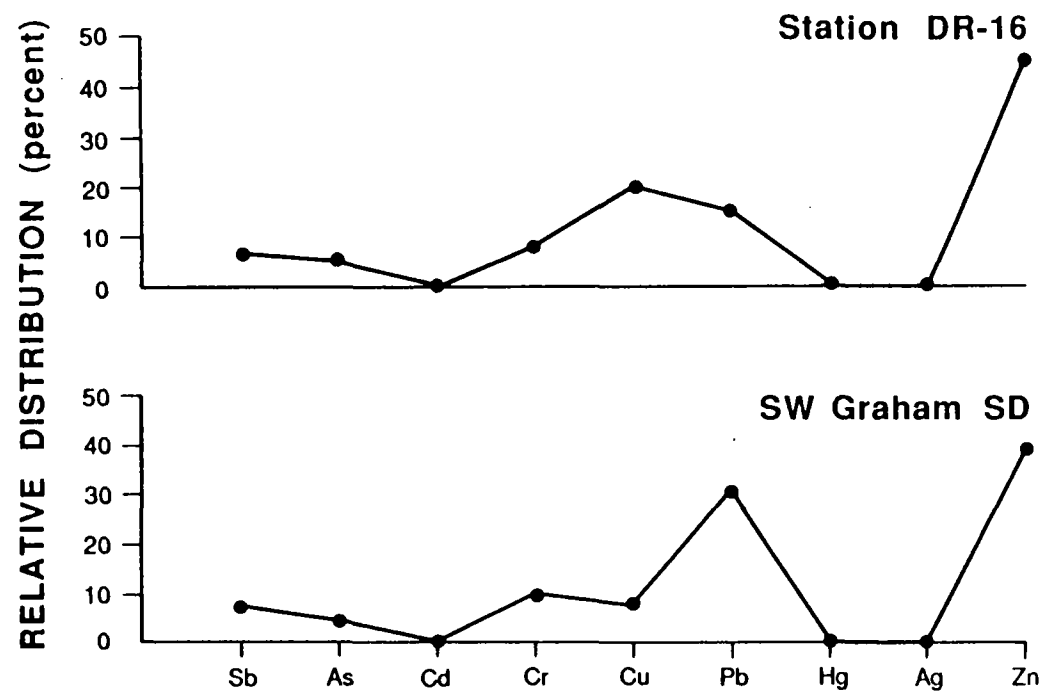


Figure 5-31. Comparison of relative percent distribution of metals in sediment from Station DR-16 and sediment from a nearby drain.

contamination at Station DR-16 at the time of sample collection, despite their close proximity to each other.

HPAH concentrations at Station DR-16 were 5-7 times greater than the HPAH concentrations at the nearest upstream (DR-13) and downstream (DR-17) centerline stations on the Duwamish River. LPAH showed a similar trend, with the concentration at Station DR-16 7-11 times greater than surrounding stations. The apparent gradient in PAH in this area indicates that there was a source near Station DR-16. The ratio of methylphenanthrenes to phenanthrene in the DR-16 sediments and at surrounding stations (0.026-0.41) indicates that PAHs in this area were associated with combustion-related fuel sources.

No specific sources of HPAH have been documented in the area adjacent to Station DR-16. Station DR-16 was located adjacent to an area that was dredged by Kaiser in 1984 (see Figure G-7 in Appendix G). Approximately 15,300 yd³ were removed from the area immediately north of the station. Resuspension and deposition of sediments during the operation may have affected the sediments at Station DR-16.

The HPAH contamination at Station DR-16 may be related to historical land-use activities. The west shoreline of the Duwamish River adjacent to Station DR-16 has undergone considerable change. The area now occupied by Terminal 115 was formerly the main channel of the Duwamish River. This area was filled with sediments dredged from the Duwamish River over an approximately 20-yr period. A cement plant and lumber yard were located in the southwest corner of what is now Terminal 115. The terminal was completed in 1975 (Blomberg, G., 3 December 1987, personal communication) and is now used for marine cargo shipment. The SW Graham SD runs along the north border of Terminal 115. PAH contamination may be associated with the filling operations.

A chemical company (MST), operated a metal recycling plant on the north end of Terminal 115 beginning in the early 1950s. Metal recycling continues at this site, although under different ownership (Blomberg, G., 3 December 1987, personal communication). Aerial photos from 1963 to 1975

show that MST had constructed sludge dewatering ponds in this area. The ponds were unlined and approximately 6 ft deep. In 1969, the ponds received an estimated 3,500 gal/wk of wastes (Sweet-Edwards & Associates and Harper-Owes 1985). Groundwater would be the most likely ongoing transport pathway if PAH compounds were present in the sludges disposed of in the ponds.

An organic chemical plant that manufactured synthetic resins, formaldehydes, pentachlorophenol, and hydrochloric acid also operated in the area prior to 1958 (Sweet-Edwards & Associates and Harper-Owes 1985). Until 1955, the plant discharged untreated wastes into the Duwamish River. In 1955, settling basins were installed to treat the wastewater prior to discharge to the river. This area has since been filled and paved during Terminal 115 construction and may have contributed contaminants to the river via groundwater transport.

6.0 SUMMARY

The source data were evaluated to identify problem CSOs and storm drains in the Elliott Bay project area and to link specific contaminant sources (e.g., drains, groundwater inflow, waterfront land-use activities, and spills) to the high-priority problem areas in the receiving environment (Seattle South Waterfront, West Waterway I and II, and North Harbor Island I and II; and problem stations NS-01, EW-05, AB-01, KG-01, KG-05, KG-06, DR-12, and DR-16). Problem CSOs and storm drains sampled during this study were ranked based on:

- The number of problem chemicals identified in the drain sediments
- The magnitude of exceedance of reference area sediment chemistry conditions for all problem chemicals identified in the drain sediments
- The contaminant loading index for each drain.

Based on these three criteria, the following drains in the Elliott Bay project area were identified as high-priority problem drains:

- Fox S. CSO/SD (116)
- Michigan CSO (W039)
- Slip 4 CSO/SD (117)
- Duwamish SD
- SW Lander CSO/SD (105)

- SW Hanford CSO/SD (162)
- Slip 6 SD
- Michigan SD.

Two additional drains, the S. 96th SD and the SW Florida CSO/SD (098), have been assigned a high priority because ongoing sources have been documented in their drainage basins. Numerous other drains in the project area were identified as contaminant sources (see Section 4.3) to the receiving environment based on the drain sediment chemistry results. The eight drains listed above are the drains that ranked as the highest priority based on the three ranking criteria.

In some cases, it was possible to associate specific sources (i.e., CSOs, storm drains, waterfront land-use activities, groundwater inflow, or spills) to the problem areas identified in the offshore sediments (PTI and Tetra Tech 1988). The following criteria were used to link specific sources to the offshore problem areas:

- Proximity of a drain outfall, or other suspected source to the problem area in the receiving environment
- Similarities in the problem chemicals identified in the drain sediments and the offshore sediments
- Similarities in the relative distributions of chemicals within a related group of chemical compounds (i.e., metals, LPAH, and HPAH) within the drain and receiving environment sediments
- The spatial distribution of contaminants in the offshore sediments

- Available information on past or ongoing practices that may contribute to the contamination observed in the receiving environment.

The results of the source to receiving environment evaluations and the drain rankings are summarized in Table 6-1. Sources that were associated with contamination observed in the receiving environment, as well as the high-priority drains that were identified based on the drain sediment chemistry results are listed in the table. However, it must be emphasized that there were probably other contaminant sources in the project area. The sources listed in Table 6-1 were the sources where there was strong evidence linking them to a problem contaminant in the offshore sediments.

In some cases, no specific sources could be identified in a particular problem area or for a specific problem chemical. For example, no ongoing sources of contamination could be identified in the Seattle South Waterfront problem area. Contamination in this problem area may have been caused by historical activities. However, further investigation is required to confirm that there are no ongoing contaminant sources in this problem area. The concentration of 4-methylphenol exceeded HAET in numerous offshore and drain sediment samples. No specific sources of this contaminant were identified in the project area. Further investigation of potential uses and sources of 4-methylphenol is required to document the contamination observed in the project area.

TABLE 6-1. SUMMARY OF THE HIGH-PRIORITY HISTORICAL OR CURRENT CONTAMINANT SOURCES IDENTIFIED IN THE ELLIOTT BAY PROJECT AREA ^a

	Number of problem chemicals in drain sediments > 10	Sum of the individual EARs for problem chemicals in drain sediments > 20,000	Loading index for problem chemicals > 1,000,000	Contaminant source identified in drainage basin or service area	Drain outfall or waterfront activity located near a high-priority problem area in receiving environment	Problem chemicals in source same as problem chemicals in receiving environment	Distribution of contaminants in source matches distribution of contaminants in offshore sediments	Evidence that source is associated with contamination offshore due to historical or ongoing practices
SEATTLE NORTH WATERFRONT								
• DRAINS								
Denny Way CSO (W027)	○	○	○	○	●	●	●	NA
EAST WATERWAY								
• DRAINS								
SW Hanford CSO/SD (162)	○	●	●	●	●	●	●	NA
Hanford CSO (W032)	○	○	○	○	●	○	●	NA
• OTHER SOURCES								
Groundwater	NA	NA	NA	NA	●	●	NE	●
WEST WATERWAY								
• DRAINS								
SW Lander CSO/SD (105)	○	●	●	●	●	●	○	NA
SW Florida CSO/SD (098)	○	○	○	●	●	● ^b	○	NA
• OTHER SOURCES								
Groundwater	NA	NA	NA	NA	●	NE	NE	●
Lockheed Shipbuilding Company	NA	NA	NA	NA	●	NE	NE	●
NORTH HARBOR ISLAND								
• DRAINS								
Lower Longfellow Creek	○	○	○	○	●	●	○	NA
• OTHER SOURCES								
Wyckoff Company	NA	NA	NA	NA	●	●	●	●
Todd Shipyard Corporation	NA	NA	NA	NA	●	NE	NE	●
Lockheed Shipbuilding Company	NA	NA	NA	NA	●	NE	NE	●
UPPER DUWAMISH ESTUARY								
• DRAINS								
Fox S CSO/SD (116)	●	●	○	●	●	●	○	NA
Michigan CSO (W039)	●	○	○	○	●	○	○	NA
Slip 4 CSO/SD (117)	●	●	○	○	○	○	○	NA
Duamish SD	○	●	○	○	○	○	○	NA
Michigan SD	●	○	○	○	●	○	○	NA
Slip 6 SD	●	○	○	○	○	○	○	NA
• OTHER SOURCES								
Marine Power and Equipment Company	NA	NA	NA	NA	●	●	●	●

^a Sources include CSOs and SDs (including individual sources located within each service area or drainage basin), land-use activities at properties adjacent to the waterways, groundwater inflow, and spills.

^b Resampling of a catch basin in the drain after the line had been cleaned showed that the Wyckoff facility is an ongoing source of contaminants to the drains (Sample, T., 27 March 1987, personal communication).

● Relationship observed

○ Relationship not observed

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